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COMPUTER SIMULATION MODEL OF THE IPSWICH RIVER BASIN

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COMPUTER SIMULATION MODEL
OF
THE IPSWICH RIVER BASIN

By
Alan W. Burns & Ivan C. James II

U. S. GEOLOGICAL SURVEY

MAY 1972

Prepared in cooperation with the
UNITED STATES DEPARTMENT OF THE INTERIOR
Geological Survey
Published with the approval of the Director, U. S. Geological Survey

Publication No. 6317 approved by Alfred C. Holland, State Purchasing Agent

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ABSTRACT

Consideration of all proposals made by towns and regional planners for development of water resources in the Ipswich River basin is impractical using traditional hydrologic techniques. A computer simulation model has been written to assess the different development proposals. The model simulates the hydrology and operation of water-supply systems in the basin at given levels of demand and particular sequences of streamflows. Hydrologic simulation distributes incremental gaged runoff to each tributary drainage area and computes the effects of groundwater withdrawals on streamflow. Operational simulation of the water-supply systems takes water from supply sources, diverts streamflow to storage reservoirs, and transfers water between reservoirs. Established operating rules are observed; for example, no diversions are allowed below a minimum discharge, and diversions are allowed only in winter and spring. Model results indicate the relative abilities of different developmental plans and provides a rational means of decision making to be used with costs, legislative feasibility, and environmental impact.

INTRODUCTION

Communities in and near the Ipswich River basin are facing water-supply problems caused by the rapid population growth since 1950. The expected expansion of the Boston metropolitan area will accentuate these problems. Even the adequacy of the water-supply systems of towns whose population has remained level has been reduced by increased per capita consumption and increased utilization of the same basic water resource, the Ipswich River, by other towns upstream. Plans for development of additional supply sources are being considered in several towns and at the regional and state level. Some of these plans may conflict with other alternatives for integrated management of the basin's resources. The well-established need for additional sources, along with the substantial lead time for authorization, financing, and construction have led to several regional proposals.

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A necessary requirement for effective development of water-supply sources in this basin is a method for evaluating the various alternatives that have been proposed. To meet this requirement, a computer simulation model was written to assess alternaitve plans for development of water resources within the basin.

The model simulates the operations of each town's supply system in meeting its demand with the use of surface water and/or groundwater. The model evaluates sets of supply systems at desired levels of demand. Results obtained from the model indicate success or failure for a given set of supply systems and level of demand - a failure being a water deficit for one or more towns. Thus, the model can be used by water resource manages to compare and judge the effectiveness of alternatives. Although the model does not specify the best alternative, it provides valuable information for the manager, who must then consider other factors, such as engineering efficiency, costs, legislative actions, financing, inter-town cooperation, pollution, and environmental impacts.

The model has been designed for the Ipswich River basin, but has been kept as general as possible for use in other basins. Three physical characteristics of the Ipswich River basin that must be present in another basin to use the model are:

1) one main artery - because no major tributaries enter the Ipswich River, the model was developed without branching routines. However, the modification needed to model a basin with more than one main branch would not be difficult to program.

2) localized aquifer - because most of the groundwater is in small, isolated aquifers with close hydraulic connection to the stream, the model was not written to simulate the entire aquifer but to simulate the response of streamflow to pumping wells. More complex models are required in basins with extensive aquifers.

3) off-channel surface-water storage - because there are no adequate sites for on-channel reservoirs, the model was developed to use only pumped storage reservoirs. However, the modification needed to model a basin with mainstream reservoirs would not be difficult to program.

METHODOLOGY OF THE MODEL

Parameters describing the physical characteristics of the supply-systems, the disposal systems, and the river basin are data required for the model. Physical objects, such as tributaries, reservoirs, points of diversion, wells, gaging station, and towns, are coded in a spatial concept, which allows the computer to interpret geographical locations. The river basin is divided into several smaller subbasins, each identified by a point on the river, which is referred to as a node (fig. 1). These subdivisions are made so that every physical object of the same type must lie within different subbasins. For example, two reservoirs must lie within two separate subbasins. However, a subbasin may contain all the different types of physical objects. For example, a town, a reservoir, a well, and a tributary may lie within the same subbasin (fig. 2). The exception to this is that any number of wells, whose effects are on the same tributary, may be within the same subbasin. Wells, reservoirs, or towns that are outside the drainage basin of the river but that still affect the basin in some way are coded within subbasins defined to have zero drainage area (relative to the river being modeled) (fig. 2). After all subbasins have been defined, their respective nodes are numbered in downstream order.

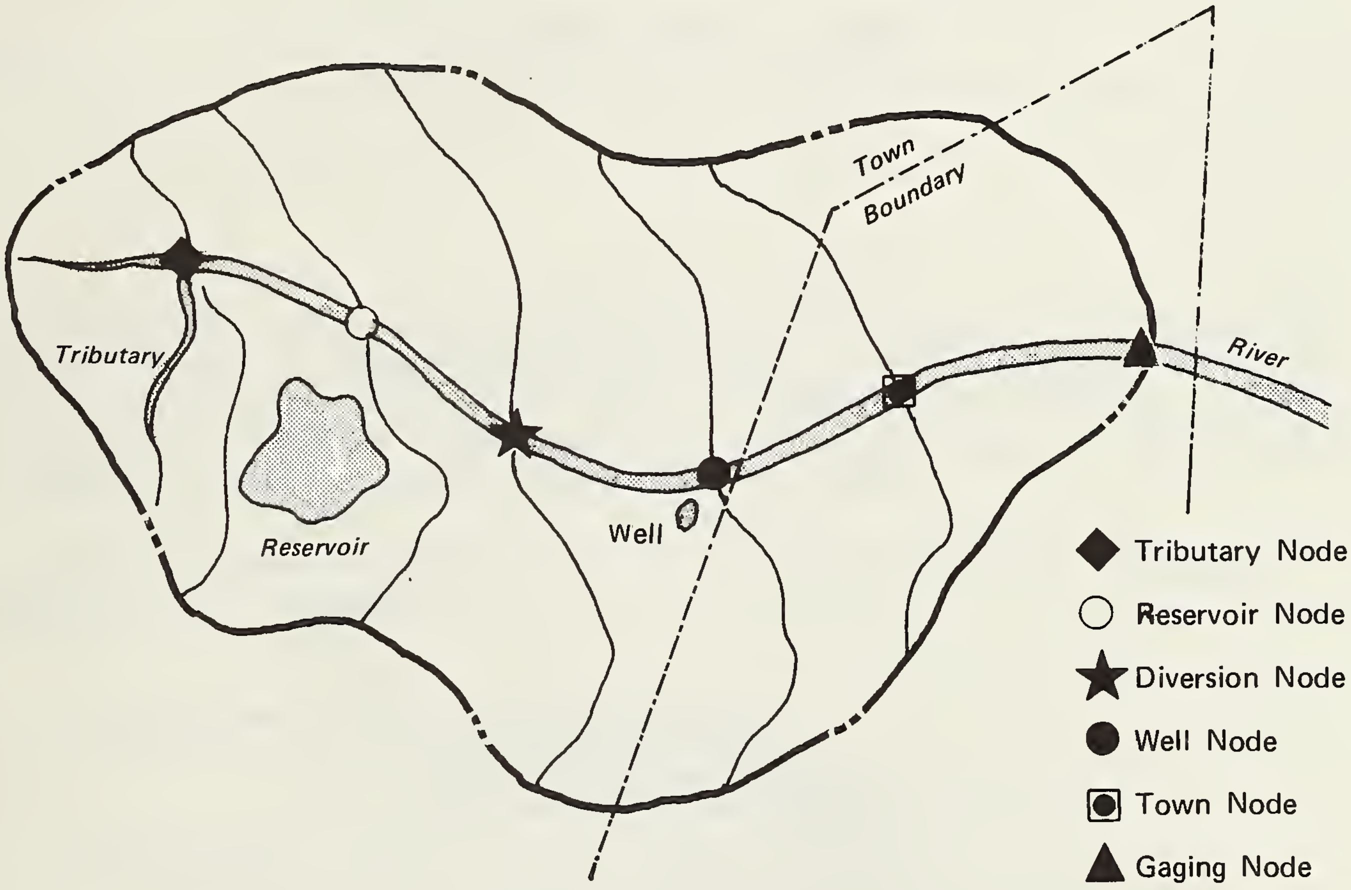


Figure 1 SUB-BASINS IDENTIFIED BY DIFFERENT TYPES OF NODES

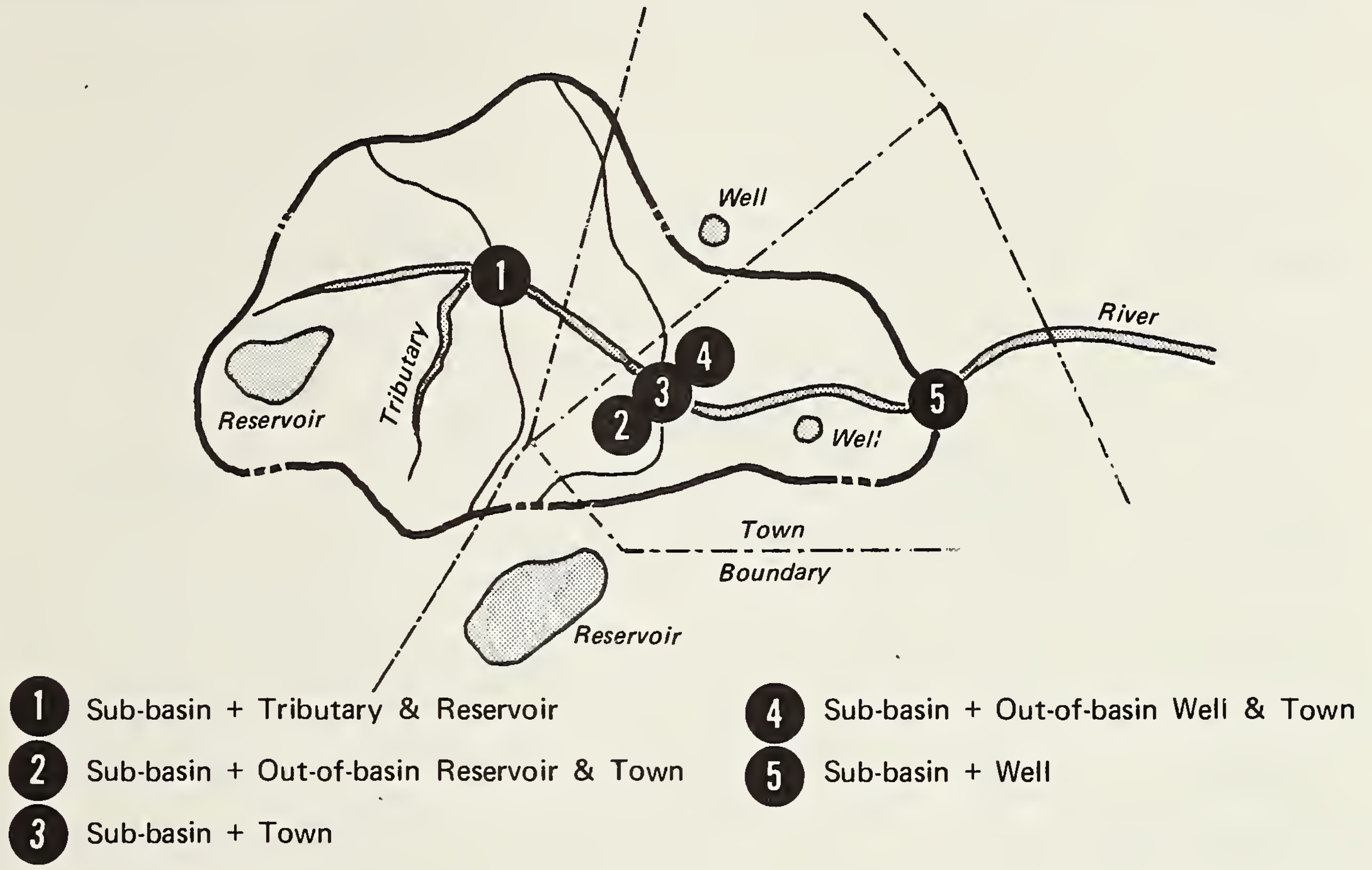

Well
River
Tributary
Reservoir
① ② ③ ④ ⑤
Well
Town
Boundary
Reservoir
① Sub-basin + Tributary & Reservoir
② Sub-basin + Out-of-basin Reservoir & Town
③ Sub-basin + Town
④ Sub-basin + Out-of-basin Well & Town
⑤ Sub-basin + Well

Figure 2 MULTIPLE USE OF NODES

The model simulates the continuous interactions of the real world by cycling (fig. 3) through discrete "passes" (a pass being a specific function executed on a subset of nodes in downstream order) on a monthly time interval. Monthly flows for each of the two gaging stations within this basin are the hydrologic input for the model.

The first pass distributes the incremental runoff of the gaging stations to each subbasin.

$R_g = Q_g/DA_g$ where R = incremental runoff
Q = incremental discharge
DA = incrimental drainage area
g = subscript indicating gaging station index

$Q_i = R_j \times DA_i$ where i = subscript indicating nodal index
j = subscript indicating respective gaging station index

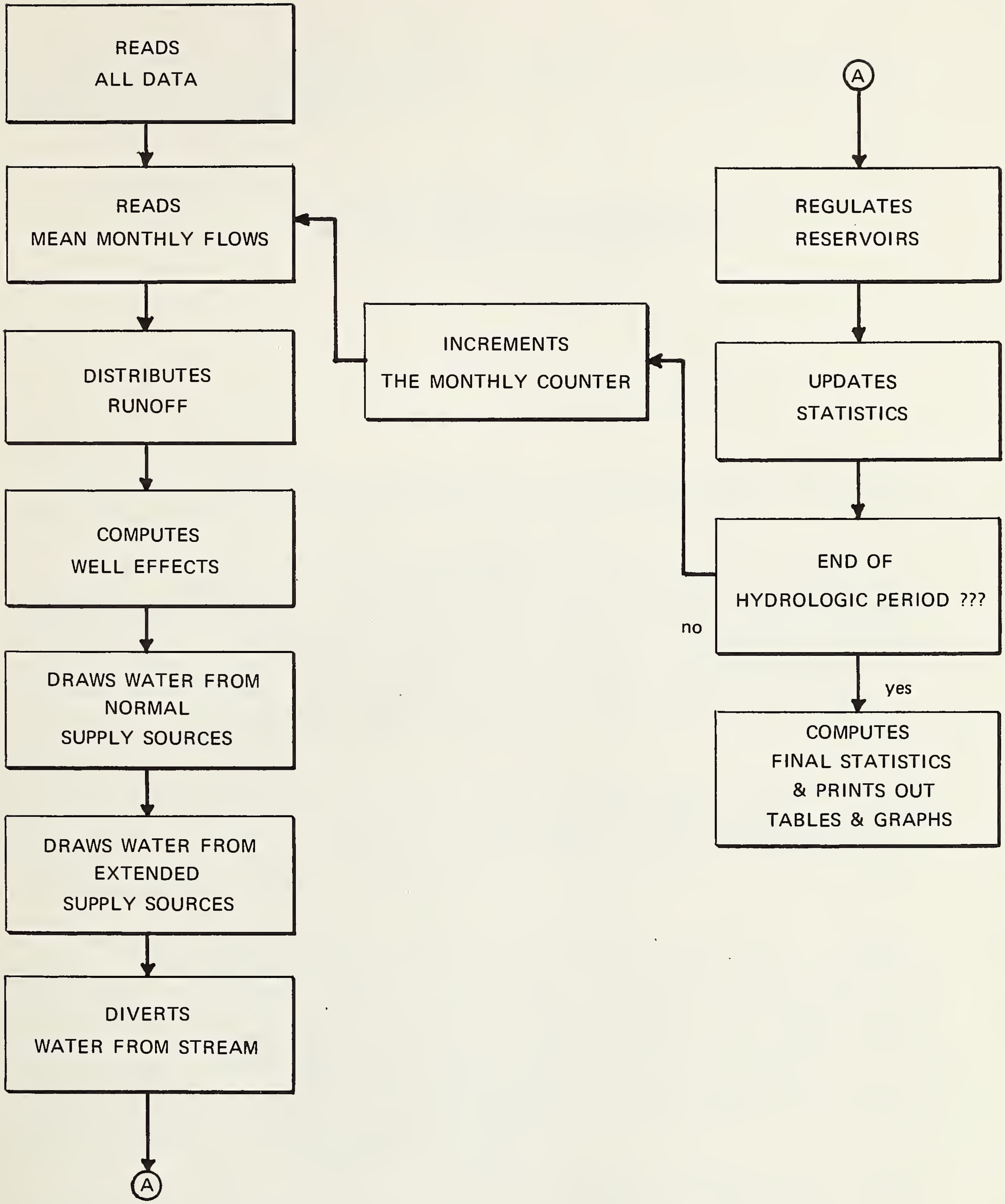


Figure 3 FLOWCHART OF THE MODEL

When there is a reservoir within a subbasin, the monthly inflow is computed from the drainage area of that reservoir and the average of the runoff for all the discharge records.

$I_k = \bar{R} \times DA_k \times C$ where I = reservoir increase
$\bar{R}$ = average of the runoff for all the discharge records used
C = constant to convert rate to volume per month
k = subscript indicating reservoir index

If water is diverted from another river to augment flow, it is added in at the node corresponding to the real geographic location.

The second pass accounts for streamflow depletion resulting from groundwater withdrawals. Streamflow depletion computed by a method described by Jenkins (1970) is based on well pumpage, distance from the well to the stream, transmissivity, and specific yield. The cumulative effect on stream flow is obtained by summing the effects of each month's pumpage. Whether this depletion of streamflow is interpreted as interception of groundwater that would have become streamflow or as infiltration of existing streamflow is not important to the model.

Characteristically, the aquifers are recharged every spring and reach their maximum yearly storage during spring floods (Sammel and others 1966). To simulate the spring recharge, the accumulated effects on streamflow for each well are reduced to zero, and an equal amount of surface runoff is prevented from becoming streamflow.

The third pass attempts to satisfy the demand of each town through use of a set of normal supply sources, which may include wells, streamflow diversions, and surface reservoir withdrawals. Each town draws water from its normal supply sources in accordance with its list of priorities until the demand is satisfied or until the sources are depleted or their capacities exceeded. Any unsatisfied demand is carried over to the next pass for further operation. As water is used by each town, a fraction of it returns to the streamflow according to the value of its sewage function for that month. (See System Parameter Definition.)

The fourth pass attempts to satisfy any demand not met by the normal supply sources from a set of extended supply sources. These sources may

include wells, surface reservoir withdrawals, and purchase of water from a source having no effect on the basin's hydrology. Any town that was unable to meet its demand through its normal supply sources attempts to fulfill the remaining demand from its extended sources until the demand is met or the sources are depleted or their capacities exceeded. Any part of the demand still not satisfied is recorded as a failure of the system for that month.

The fifth pass diverts streamflow to pumped storage reservoirs. Three factors limit the amount of water diverted for each reservoir:

1) The amount of water needed to fill the reservoir.

2) The constricting factor of pump and pipe size.

3) The amount of water above the legally defined minimum discharge that must flow past the diversion point.

The sixth pass diverts water from one reservoir to another. This is used for several systems where the stream diversion is to a reservoir that is not directly drawn on by the treatment plant. Three factors limit the amount of water diverted from one reservoir to another:

1) The amount of water needed to fill the receiving reservoir.

2) The constricting factor of pump and pipe size.

3) The amount of water in the distributing reservoir.

Upon completion of these six passes, the monthly time interval is incremented to the next month, a new set of mean monthly flows are read into the model, and the entire set of operating passes is repeated. This cycling is continued for the prescribed number of months in the simulation period.

SYSTEM PARAMETER DEFINITION

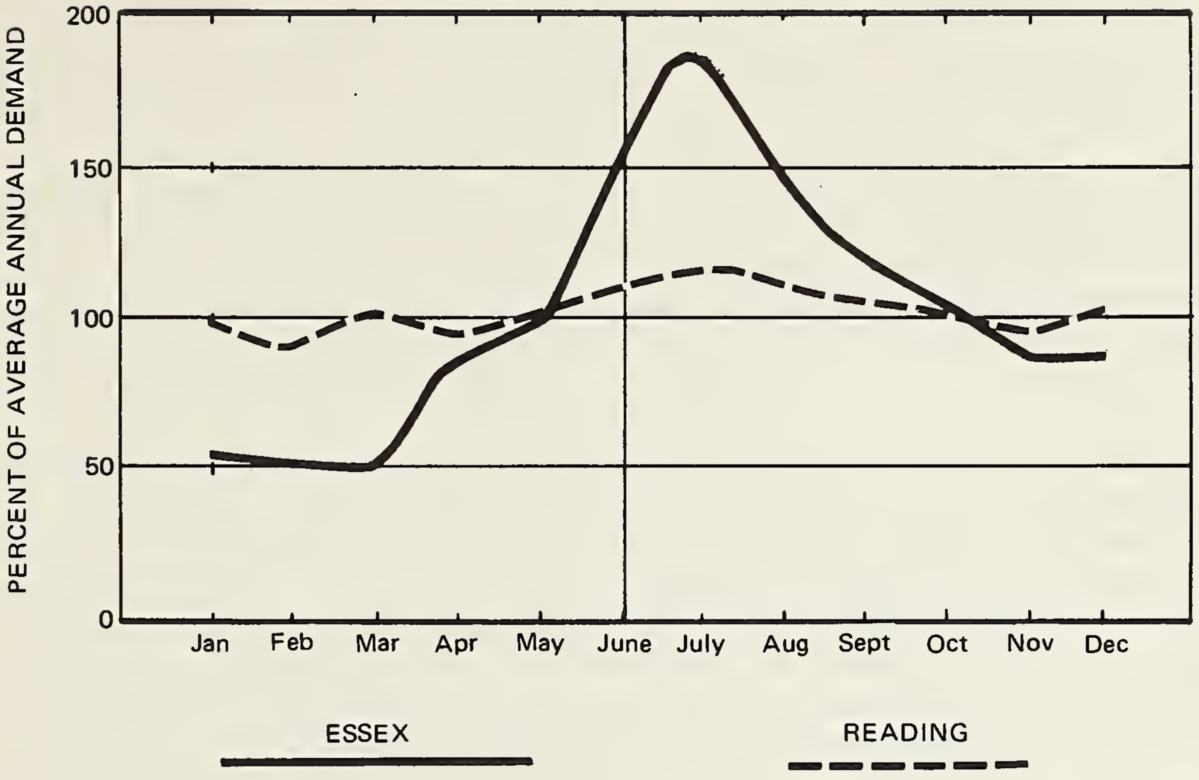
Extensive data collection is necessary to provide physical and operational parameters for the simulation program. The model structure and the level of detail required in the data are designed to make the results fit the scale of decisions faced. If every detail were used, the entire project would be merely a data collecting project. The model would be unique and could not be used in another basin, and its usefulness in decision making would be lost in the complexity of details. On the other hand, the data must be accurate and specific enough to describe the pertinent operating characteristics of the water-supply systems. Refinement of the data and parameters are carried only to the extent that further refinements do not improve the results.

Some of the parameters required for modeling are measurable physical characteristics. These include the drainage area of each subbasin and gaging station. The usable storage capacity and drainage area of reservoirs are recorded. Special codes in the data input indicate whether a reservoir is outside the basin's drainage boundary and whether a reservoir receives diverted river water or water transferred from another reservoir. The maximum capacity of either pump sizes or pipe sizes between river and towns, river and reservoirs, two reservoirs, and reservoirs and towns is necessary. Wells must be located within their subbasin and the downstream, noncontributing drainage area computed. The pumping capacity of each well is recorded, and a special code indicates which town uses the well. The effects on streamflow caused by well pumpage are computed for each well from the transmissivity and specific yield of the aquifer and distance to the stream. A special code indicates the subbasin for each town and each model to be used as an observation node.

Several other parameters are not directly measurable and require engineering analysis and hydrologic judgment. These parameters, which are held constant and used statically in discrete steps in the model although in reality they are dynamic, may cause the deviations between simulated results and actual occurrences.

A very important parameter in the model is the demand for water. Demand is not constant throughout the year, so an average demand is distributed by a time-demand relationship (fig. 4). The curve computed for each town is based on three representative years, in which demand was not affected by water-use restrictions. The model does not consider maximum daily demands of each town system but considers these demands a problem of the town's distribution system rather than the supply system. Projected average daily demands from 1975 to 2020 in 5-year increments for each town are needed for modeling proposed supply systems for stage-development analysis. For years in which estimates are not available, average daily demands must be interpolated or extrapolated.

The sewage return functions for each town is an estimate of the fraction of the water pumped to the town that returns to streamflow through sewage or septic tank effluent. The percentage is zero for sewered towns in which the sewage is pumped out of the basin. For sewage treatment plants within the basin, the return function is computed under the assumption of 1) complete return of water used by households, and 2) loss of water used for outside purposes. For septic tank effluent, a function was developed that returns most of the used water to streamflow during the winter and spring but reduces the percentage to a low level in summer, reflecting both outdoor use of water and increased evapotranspiration. The septic tank function and proper sewered function are weighted according to the percentage of water users that are sewered.



CURVES TO DISTRIBUTE AVERAGE ANNUAL DEMAND TO EACH MONTH

Figure 4

Another important parameter is the operating rules of a town in using its supply sources. These rules, which are governed by legislative acts, engineering feasibility, and human tradition, are variable in time, but in the model they must be held constant. At every diversion point on the river, the legislature has established minimum discharges, which must be exceeded before pumping is allowed. The legislature restricts the months when diversions are allowed. Within the model, water is considered to be drawn from only one source at a time, and thus, all sources are coded in order of priority. This priority list is formed to approximate actual procedures as closely as possible.

HYDROLOGIC DATA SELECTION

Performance of a water-supply system is obviously directly related to hydrologic conditions in the basin. Because hydrologic conditions are dynamic and unpredictable, it is not reasonable to design a system from one sequence of hydrologic events and to expect them to be repeated in the future. For example, water-supply systems that respond well to a long, mild drought may become critically short during a short, severe drought. Therefore, the response of a system to one particular sequence of hydrologic events may not be a particularly good measure of the reliability of that system.

Severity and duration of dry periods must be considered in estimating the frequency of failure of a water-supply system. To achieve any stability in this measure of the system's performance, many more combinations of events are needed than are usually available in historic records. The costs of improving a supply system so that it can survive a drought of certain severity are similar to purchase of insurance--the higher the premium paid, the greater the coverage of the policy. Because these insurance investments in an improved system may be large, a balance must be struck between accepting some risk and investing in the next unit of a supply system before its need is fully realized.

The hydrologic input for the model is a set of natural mean monthly flows, as recorded at the gaging stations, adjusted for upstream diversions. Selection of the set of discharges to be used influences the results of the model significantly. The 10 years of historic record from 1960 to 1969, used for most of the model runs, includes some normal years, a severe drought, and the maximum instantaneous peak of record. The 40 years of historic record from 1931 to 1970 was used to check the performance of hypothetical supply systems on droughts of shorter duration and severity than that of the mid 1960's.

Model results are influenced by assumed initial reservoir storages. The assumed initial storage in each reservoir should reflect some normal or typical condition for the supply systems under consideration. The method used to achieve typical initial storage conditions is to simulate 2 years of water-supply operation with median monthly discharge data. Resulting final reservoir storages from this period are used as initial storages for the period of simulation for which performance statistics are kept.

Use of synthetic flows can be advantegeous when a response of a supply system to a large number of possible sequences of hydrologic input is needed. These flows are generated in a way that maintains the pertinent statistics of the historical record (Fiering & Jackson 1971). Synthetic flows can be used for a more detailed investigation of a small number of proposed supply systems after screening several proposals, using the historical hydrology.

MODEL RESULTS

The model can be used by the water resource manager only if he can interpret the computer output correctly. To interpret the output, he must first understand how to read the tables (see Appendix IV for examples) and know what output options are available.

The primary table in the computer printout lists:

1) nodes along the river by some convenient name
2) usable storage capacity of a reservoir within that subbasin
3) maximum storage level reached by a reservoir during the entire simulated hydrologic period
4) minimum storage level reached by a reservoir during the entire simulated hydrologic period
5) total amount of water diverted from the river to a reservoir within the subbasin
6) total amount of water brought in from outside the basin by a supply system
7) maximum monthly amount of water brought in from outside the basin by a supply system during the entire simulated hydrologic period
8) accumulated deficits for a town during the entire simulated hydrologic period.

The only other listing that is not optional to the model, is an automatically printed line of the town name, the amount of a water deficit and the month it occurred, every time a supply system fails to meet a demand.

The optional listings are triggered by certain codes in the input deck. These include:

1) A two-part table, in which the first part lists each town with its supply system and each source in order of its priority and its capacity; the second part lists every reservoir that either receives water diverted from the river or that transfers water to another reservoir. The pump-pipe size is also listed.
2) A printed line giving the quantity of water imported into the basin to augment the river each month.
3) A printed line giving the quantity of water diverted by a reservoir from the river each month.
4) A printed line giving the quantity of water transferred from one reservoir to another each month.

5) A table that lists maximum monthly discharge and minimum monthly discharge during the entire simulated hydrologic period and a flow-duration table for any node desired.

6) A table that lists the monthly discharge and/or the storage level at any node desired for the enire simulated hydrologic period.

7) A hydrograph of the monthly discharge and/or storage level at any node desired for the entire simulated hydrologic period.

8) A special graph of any other time series from the model operation. However, this option takes some understanding of programming, as it calls a dummy subroutine, and the series to be graphed must be defined in this subroutine.

Although most of the listings and tables are self-explanatory, there are a few idiosyncrasies of the model. For instance, a reservoir may go dry as a town draws water from it, but, before the statistics for that month are updated, that reservoir may have an inflow from another reservoir or from a diversion of the river. In this case, if the reservoir is the town's only source, a deficit would have been printed, and yet the reservoir would not be listed as ever having gone dry. These apparent ambiguities come from the necessary simplifications made in the mathematical concepts of the model; the pertinent one in this case is the discrete monthly approximation of processes that happen continuously. This approximation emphasizes the importance of experience and familiarity in interpreting the model results.

Care should be taken to check the frequency and severity of deficits in the results of the model. Deficits may reflect a constraint in the supply system, a severe hydrologic condition, or possibly a mistake in coding the intended supply system for that run. Each of these has quite a different meaning, and the analyst should check each set of outputs carefully before interpreting that run or preparing the next run.

SUMMARY

A simulation model to aid in water resource planning for the Ipswich River basin has been developed and utilized. The functional operation of the model components and the procedures for converting an alternative development plan into input parameters to the computer model are described to allow the reader to become familiar with the philosophy and capabilities of the model. A proficient operating ability with this model can be gained only through a thorough investigation of the model structure and some experience in its use, based on documentation provided in the appendices.

Application of the model to any particular problem is the responsibility of the user. Reasonableness of the combinations and linkages of the chosen supply-system components are particularly important. Selection of criteria, such as the hydrologic sequence to design for, may have a substantial impact on the model results in some cases.

The model is now ready for use in assessing many proposals on a quantitative basis. Constructive criticism of this report may lead to changes and additions to the model, some of which are already under consideration. Future developments in this study will have to consider whether activities such as costing, environmental impact assessment, and benefit distribution should be done internally or externally from the computer model.

APPENDIX I

DEFINITION OF PROGRAM VARIABLES

The following is a list of the more important variables within the program and their definitions.

A(I) - The plotting value for one of 4 time series in the Ith month.

ADD - The amount of water returned to streamflow from the sewage function.

B(I) - The plotting value for one of 4 time series in the Ith month.

C(I) - The plotting value for one of 4 time series in the Ith month.

CLASS(I) - The Ith discharge used as an interval for the frequency table.

CONSUP(I) - The average daily demand for the Ith town.

D(I) - The plotting value for one of 4 time series in the Ith month.

DA(I) - The drainage area of the Ith discharge record station.

DELTA - The width of an interval during plotting.

DEMAND(I,J)- Two definitions:

1) when read in, the percentage of the average daily demand for the Ith town in the Jth month.

2) when multiplied by the respective average daily demand (CONSUP), the demand for the Ith town in the Jth month.

DIS(I) - The mean monthly discharge of the Ith discharge record station.

DIVERT - The amount of water diverted from the river.

EFF(I,J) - The accumulated well effects for the Ith well in the Jth month.

FORMT - The values used for setting up variable formats FRMAT and FRMATT.

FREQ(I,J) - The percentage of time the discharge of the Ith node is within the Jth interval.

FRMAT - A variable format to print the node name for a flow trace or storage level trace.

FRMATT - A variable format to print the discharge or storage level for a flow trace or a storage level trace.

GWMAX(I,J)- The well pumpage capacity for the Ith town in the Jth month.

GWUSED - The amount of water pumped by a well.

IDRZEN(I) - A code indicating the node form which diversions are made to a reservoir in the Ith subbasin.

IFILST(I) - A code indicating the subbasin of a reservoir to which water is transferred from a reservoir in the Ith subbasin.

IFLAG - A code indicating the number of towns that could not meet their demand with their normal sources.

IFTIME(I) - The number of months of recharge that will be computed in the Ith month.

IITIME - The monthly counter ranging from 1 to the total number of months of hydrologic data.

IMPMAX(I) - The pump capacity at an imported augmentation source in the Ith month.

IMPMIN(I) - The minimum flow that must be exceeded for diversion from an imported augmentation source in the Ith month.

IMPNOD - The node where an imported augmentation diversion enters the river.

IMPREC - A code indicating which of the discharge records is the imported augmentation source.

IN - The standard input file code.

IORDER(I) - The code for the subbasin of the reservoir that diverts water from the river in the Ith order.

IPRELM - The number of months in an initial simulation period that stabilizes reservois and well effects.

IRTURN(I) - The node to which the sewage of the Ith town returns to the streamflow.

ITIME - The monthly counter cycling from 1 to 12.

ITITLE - Two definitions:
1) In the mainline, an 80 column title card used to give a brief description of the alternative being analyzed.

2) In the plot routine, a descriptor to define what is to be plotted:
to plot a storage level hydrograph; ITITLE - STOR
to plot a discharge hydograph; ITITLE = FLOW.

ITRZFL - A code indicating whether a discharge trace should be stored.

ITRZST - A code indicating whether a storage level trace should be stored.

IVAR(I) - A code indicating which of the four time series is to be plotted.

LABEL(I) - The name of the Ith variable in the input data check.

LINE(I) - The Ith position on one line in the hydrograph.

MAXCAP(I)- The usable storage capacity of the reservoir at the Ith subbasin.

MAXMDC(I)- The maximum amount of water obtained by the Ith town from some external source in one month.

MAXST(I) - The highest storage level reached by the reservoir in the Ith subbasin.

MDCCAP(I)- The capacity of the Ith town's connection to some external source.

MDCUSE - The amount of water obtained from some external source.

MINST(I) - The lowest storage level reached by the reservoir in the Ith subbasin.

MONTH(I) - The three letter abbreviation for the Ith month.

NNODE - The number of nodes.

NOBS - The number of observation nodes.

NODE - The number of the node to be used for plotting a hydrograph.

NODNAM(I)- A twelve character name for the Ith node.

NPRINT - A code indicating which output options are in effect:

if evenly divisible by 2, then print each river diversion made;

if evenly divisible by 3, then print each reservoir transer made;

if evenly divisible by 5, then print each imported augmentation diversion;

if evenly divisible by 7, then print a list of the input data.

NRCRDS - The number of discharge record stations used.

NTIME - The total number of months of hydrologic data.

NTOWN - The number of towns.

NWELL - The number of wells.

OBS(I) - A list of nodes used as observation nodes.

OBSMAX(I)- The minimum discharge at the Ith observation node.

OUT - The standard output file code.

PERCNT(I,J)- The percentage of the incremental discharge of the nearest downstream gage contributed by the Ith subbasin in the Jth month.

PRIORY(I,J)- A code listing the Jth ordered supply source for the Ith town. The list is in two groups, the first eigt being normal sources, the second eight being extended sources.

For the first eight:
1 indicates wells;

2 indicates a surface water diversion;
any number greater than 2 indicates the desired reservoir's subbasin number plus 10.

For the second eight:

1 indicates an external source;

2 indicates wells;
any number greater than 2 indicates the desired reservoir's subbasin number plus 10.

Q(I) - The discharge at the Ith node.

QIMP - The amount of the imported augmentation discharge.

QQ(I) - The amount of the imported augmentation discharge at the Ith node.

RANGE - The maximum value of the time series to be plotted.

RATE - The percentage the demand is of a town's well capacity.

RECORD(I) - The discharge record that the discharge of the Ith node is computed from.

RESDA(I) - The drainage area of the reservoir in the Ith subbasin.

RESOOB(I) - A code indicating whether the reservoir of the Ith subbasin is outside the basin's drainage boundary.

RESQ - The discharge that flows into a reservoir.

RTURN(I,J) - The percentage of water used by the Ith town that returns to streamflow in the Jth month.

RUNOFF - The average of the monthly runoff (mgd/sq mi) of each discharge record station read in.

SCALE - The scaling interval printed on the plot.

STCAPY(I) - The storage level of the reservoir in the Ith subbasin.

STMAX(I,J) - The pump capacity for removing water from the reservoir in the Ith subbasin in the Jth month.

STUSED - The amount of water taken from reservoir storage.

SUBADA(I) - The drainage area of the Ith subbasin.

SUPPLY - The amount of water taken from a supply system toward meeting a town's demand.

SWMAX(I,J) - The pump capacity for diverting water directly to the Ith town without storage, in the Jth month.

SWMIN(I,J) - The minimum flow that must be exceeded before diversion at the Ith node in the Jth month.

SWMINF - A unit discharge (mgd/sq mi) used to compute minimum flows.

SWSMAX(I,J) - The pump capacity for diverting water to the reservoir in the Ith subbasin in the Jth month.

SWUSED - The amount of surface water diverted for use without storage.

TOWN(I) - The node number of the Ith town.

TTLDF(I) - The total deficits accumulated by the Ith town.

TTLDV(I) - The total diversions accumulated by the reservoir in the Ith subbasin.

TTLMDC(I) - The total amount of water obtained form some external source by the Ith town.

TYMFAC - A scale factor listing a conversion for the rate (30.44 x mgd = mg per month)

UNIT(I,J) - A unit function that account for the affect on a stream caused by pumping the Ith well in the Jth future month.

WELCAP(I,J,K) - the pump capacity of the Jth well owned by the Ith town in the Kth month.

WELL(I,J) - the well number of the Jth well owned by the Ith town.

WELNOD(I) - The subbasin number in which the Ith well is located.

WELPCT(I) - The percentage of the subbasin's drainage area upstream from the Ith well.

X(I) - The Ith preset range interval.

XCHANG - The amount of water transferred from one reservoir to another.

Y(I) - The Ith preset scale factor associated with the respective X range interval.

APPENDIX II

PROGRAM

The following is a listing of the Fortran IV source deck of the model.

```
C             IPSWICH SIMULATION MODEL - VERSION 1B  FIXED AUGUST 1971
C
C             SEE U.S.GEOLOGICAL SURVEY OPEN FILE REPORT 'COMPUTER
C        SIMULATION MODEL OF THE IPSWICH RIVER BASIN', BURNS,A.W. AND
C        JAMES,I.C.II FOR EXPLANATION OF VARIABLES AND METHODOLOGY OF
C        THE MODEL.
C
C             THIS PROGRAM WAS CODED BY A.W. BURNS, U.S.GEOLOGICAL SURVEY,
C        WATER RESOURCES DIVISION, BOSTON, MASSACHUSETTS.
C
C
C
C        THE MAINLINE MERELY INITIALIZES VARIABLES AND CALLS THE
C             SUBROUTINES.
C
C
      CCMMON    I   , ITIME, MAXCAP(60), NNODE, Q(60), STCAPY(60),
     1 TOWN(25), TYMFAC
      COMMON /M12/ DA(10), IMPMAX(12), IMPMIN(12), IMPNOD, IMPQ, IMPREC,
     1 IN, NRCRDS, NWELL, PERCNT(60,12), QQ(60), QSUBA(60), RECORD(60),
     2 RESDA(60), RESOOB(60), SUBACA(60), WELNOD(60), WELPCT(60)
      COMMON /M35/ DEFICT(25), DEMAND(25,12), GWMAX(25,12), IFLAG,
     1 IPRELM, IRTURN(25), MDCCAP(25), NTIME, NTOWN, PRIORY(25,16),
     2 RTURN(25,12), SWMAX(25,12), WELCAP(25,10,12)
      COMMON /M78/ CLASS(7), FREQ(10,8), MAXST(60), MINST(60), NOBS,
     1 OBS(10), OBSMAX(10), OBSMIN(10)
      COMMON /M568/ IDVRZN(60), IFILST(60), MAXMDC(25), NODNAM(63,3),
     1 OUT, SWSMAX(60,12), TTLDF(25), TTLDV(60), TTLMDC(25), IORDER(60)
      COMMON /M24/ EFF(60,12), UNIT(60,12), WELL(25,10)
      REAL IMPMAX, IMPMIN, IMPQ
      INTEGER RECORD, RESOOB, WELNOD
      REAL MDCCAP
```

```
      INTEGER PRIORY
      REAL MAXST, MINST
      INTEGER OBS
      REAL MAXMDC
      INTEGER CUT
      REAL MAXCAP
      INTEGER TOWN
      INTEGER WELL
      DIMENSION ITITLE(20)
C
C
      READ (5,1000) IN, OUT
C
C        READ THE TITLE OF THE DATA AND THEN PRINT IT
C
      READ (IN,1010) ITITLE
C        INITIALIZATION
C
      DO 80 J = 1,60
   80 IORDER(J) = 0
C
C        CALL SUBROUTINE 'RDPARM' TO READ ALL THE PARAMETERS
C
      CALL RDPARM
C
C        INITIALIZATION
C
      DO 60 L = 1,NNODE
      QC(L) = 0.
      DO 60 J = 1,12
   60 EFF(L,J) = 0.
C
C        RUN AN INITIAL PERIOD TO STABILIZE RESERVOIRS AND WELL EFFECTS
C
      DO 70 I = 1,IPRELM
      ITIME = I - ((I-1)/12)*12
      CALL RDFLOW
      CALL NATHYD
      CALL LOCAL
   70 CALL FILLST
C
C        INITIALIZATION
C
      DO 20 L = 1,NOBS
      OBSMAX(L) = 0.
      OBSMIN(L) = 10000.
      DO 20 J = 1,8
   20 FREQ(L,J) = 0.
      DO 30 L = 1,NTOWN
      TTLDF(L) = 0.
      TTLMDC(L) = 0.
   30 MAXMDC(L) = 0.
      DO 40 L = 1,NNODE
      TTLDV(L) = 0
      MAXST(L) = 0.
   40 MINST(L) = 10000.
C
C        INCREMENT THE MONTHLY TIME INTERVAL THROUGH THE ENTIRE RECORD
C             OF HYDROLOGIC DATA
C
      DO 10 I = 1,NTIME
      ITIME = I - ((I-1)/12)*12
      CALL RDFLOW
      CALL NATHYD
      IFLAG = 0
      CALL LOCAL
```

```
      IF (IFLAG.NE.0) CALL REGION
      CALL FILLST
   10 CALL KEPTRK
      CALL APRINT
      STOP
C
C
 1000 FORMAT (2I1)
 1010 FORMAT (20A4)
 2000 FORMAT (1H1 ////25X,20A4////)
      END
.......................................................................................................

      SUBROUTINE RDPARM
C
C
C         READS ALL OF THE PARAMETERS AND CHECKS TO SEE THAT THEY ARE
C                IN ORDER
C
C
      COMMON IITIME, ITIME, MAXCAP(60), NNODE, Q(60), STCAPY(60),
     1 TOWN(25), TYMFAC
      COMMON /M12/ DA(10), IMPMAX(12), IMPMIN(12), IMPNOD, IMPQ, IMPREC,
     1 IN, NRCRDS, NWELL, PERCNT(60,12), QQ(60), QSUBA(60), RECORD(60),
     2 RESDA(60), RESOOB(60), SUBADA(60), WELNOD(60), WELPCT(60)
      COMMON /M35/ DEFICT(25), DEMAND(25,12), GWMAX(25,12), IFLAG,
     1 IPRELM, IRTURN(25), MDCCAP(25), NTIME, NTOWN, PRIORY(25,16),
     2 RTURN(25,12), SWMAX(25,12), WELCAP(25,10,12)
      COMMON /M78/ CLASS(7), FREQ(10,8), MAXST(60), MINST(60), NOBS,
     1 OBS(10), OBSMAX(10), OBSMIN(10)
      COMMON /M568/ IDVRZN(60), IFILST(60), MAXMDC(25), NODNAM(63,3),
     1 OUT, SWSMAX(60,12), TTLDF(25), TTLDV(60), TTLMDC(25), IORDER(60)
      COMMON /S2356/ NPRINT, STMAX(60,12), SWMIN(60,12)
      COMMON /M24/ EFF(60,12), UNIT(60,12), WELL(25,10)
      COMMON /R2/ ITRZFL, ITRZST, QTRACE(120,9), FLTRAZ(120,9), IWANTX
      REAL IMPMAX, IMPMIN, IMPQ
      REAL MDCCAP
      REAL MAXST, MINST
      REAL MAXMDC
      REAL MAXCAP
      INTEGER RECORD, RESOOB, WELNOD
      INTEGER PRIORY
      INTEGER OBS
      INTEGER OUT
      INTEGER WELL
      INTEGER TOWN, TITLE
      DIMENSION LABEL(32), CONSUP(50)
      DATA LABEL / 4H    ,4HIMPC,4HRECO,4HWELN,4HTOWN,4HOBS ,4HIRTU,
     14HPERC,4HRESD,4HSUBA,4HIFIL,4HMAXC,4HSWMI,4HSWMA,4HSWSM,4HSTMA,
     24HRESC,4HDEMA,4HRTUR,4HMDCC,4HPRIO,4HWELC,4HWELP,4HWELL,4HIMPM,
     34HIMPM,4HCLAS,4HTYMF,4HDA  ,4HCONS,4HUNIT,4HIDVR /
C
C
      L = 1
      LL = 1
      READ(IN,1010)TITLE, NUM, KODE, NNODE, NTIME, NTOWN, NOBS, NWELL,
     1 NRCRDS,IPRELM,NPRINT,ITRZFL,ITRZST, IWANTX
      READ (IN,1040) ((NODNAM(I,J),J=1,3),I=1,NNODE)
      IF (TITLE.NE.LABEL(L)) GO TO 700
      L = 2
      READ (IN,1010) TITLE,NUM,IMPREC,IMPNOD
      IF (TITLE.NE.LABEL(L)) GO TO 700
      L = 3
      LL = 0
      DO 10 M = 1,NNODE,24
      LL = LL + 1
      L = 3
      LL = 0
```

```
      DO 10 M = 1,NNODE,24
      LL = LL + 1
      N = M + 23
      IF (N.GT.NNODE) N = NNODE
      READ (IN,1010) TITLE,NUM ,(RECORD(I),I = M,N)
      IF (TITLE.NE.LABEL(L).OR.NUM.NE.LL) GO TO 700
   10 CONTINUE
      L = 4
      LL = 0
      DO 20 M = 1,NWELL,24
      LL = LL + 1
      N = M + 23
      IF (N.GT.NWELL) N = NWELL
      READ (IN,1010) TITLE,NUM, (WELNOD(I),I= M,N)
      IF (TITLE.NE.LABEL(L).OR.NUM.NE.LL) GO TO 700
   20 CONTINUE
      L = 5
      LL = 0
      DO 30 M = 1,NTOWN,24
      LL = LL + 1
      N = M + 23
      IF (N.GT.NTOWN) N = NTOWN
      READ (IN,1010) TITLE,NUM, (TOWN(I),I=M,N)
      IF (TITLE.NE.LABEL(L).OR.NUM.NE.LL) GO TO 700
   30 CONTINUE
      L = 6
      LL = 1
      READ (IN,1010) TITLE,NUM, (OBS(I),I=1,NOBS)
      IF (TITLE.NE.LABEL(L)) GO TO 700
      L = 7
      LL = 0
      DO 40 M = 1,NTOWN,24
      LL = LL + 1
      N = M + 23
      IF (N.GT.NTOWN) N = NTOWN
      READ (IN,1010) TITLE,NUM, (IRTURN(I), I=M,N)
      IF (TITLE.NE.LABEL(L).OR.NUM.NE.LL) GO TO 700
   40 CONTINUE
      L = 8
      DO 50 LL = 1,NNODE
      READ (IN,1020) TITLE, NUM, (PERCNT(LL,J),J = 1,12)
      IF (TITLE.NE.LABEL(L).OR.NUM.NE.LL) GO TO 700
   50 CONTINUE
      L = 9
      LL = 0
      DO 60 M =1,NNODE,12
      LL = LL + 1
      N = M + 11
      IF (N.GT.NNODE) N = NNODE
      READ (IN,1030) TITLE,NUM, (RESDA(I),I = M,N)
      IF (TITLE.NE.LABEL(L).OR.NUM.NE.LL) GO TO 700
   60 CONTINUE
      L = 10
      LL = 0
      DO 70 M = 1,NNODE,12
      LL = LL + 1
      N = M + 11
      IF (N.GT.NNODE) N = NNODE
      READ (IN,1030) TITLE, NUM, (SUBADA(I),I = M,N)
      IF (TITLE.NE.LABEL(L).OR.NUM.NE.LL) GO TO 700
   70 CONTINUE
      L = 11
      LL = 0
      DO 80 M = 1,NNODE,24
      LL = LL + 1
      N = M + 23
      IF (N.GT.NNODE) N = NNODE
      READ (IN,1010) TITLE,NUM,(IFILST(I),I=M,N)
```

```
      IF (TITLE.NE.LABEL(L).OR.NUM.NE.LL) GO TO 700
   80 CONTINUE
      L = 12
      LL = 0
      DO 90 M = 1,NNODE,12
      LL = LL + 1
      N = M + 11
      IF (N.GT.NNODE) N = NNODE
      READ (IN,1030) TITLE, NUM, (MAXCAP(I),I = M,N)
      IF (TITLE.NE.LABEL(L).OR.NUM.NE.LL) GO TO 700
   90 CONTINUE
      DO 95 I = 1,NNODE
   95 STCAPY(I) = .5*MAXCAP(I)
      L = 13
      LL = 1
      READ (IN,1020) TITLE,NUM, SWMINF
      IF (TITLE.NE.LABEL(L)) GO TO 700
      AREA = 0
      DO 100 I = 1,NNODE
      AREA = AREA + SUBADA(I)
      X = SWMINF*AREA
      DO 100 J = 1,12
  100 SWMIN(I,J) = X
      L = 14
      DO 110 LL = 1,NTOWN
      READ (IN,1030) TITLE, NUM, (SWMAX(LL,J),J = 1,12)
      IF (TITLE.NE.LABEL(L).OR.NUM.NE.LL) GO TO 700
  110 CONTINUE
      L = 15
      DO 120 LL = 1,NNODE
      READ (IN,1030) TITLE, NUM, (SWSMAX(LL,J),J = 1,12)
      IF (TITLE.NE.LABEL(L).OR.NUM.NE.LL) GO TO 700
  120 CONTINUE
      L = 16
      DO 130 LL = 1,NNODE
      READ (IN,1030) TITLE, NUM, (STMAX(LL,J),J = 1,12)
      IF (TITLE.NE.LABEL(L).OR.NUM.NE.LL) GO TO 700
  130 CONTINUE
      L = 17
      LL = 0
      DO 140 M = 1,NNODE,24
      LL = LL + 1
      N = M + 23
      IF (N.GT.NNODE) N = NNODE
      READ (IN,1010) TITLE,NUM, (RESOOB(I),I=M,N)
      IF (TITLE.NE.LABEL(L).OR.NUM.NE.LL) GO TO 700
  140 CONTINUE
      L = 18
      DO 150 LL = 1,NTOWN
      READ (IN,1020) TITLE,NUM, (DEMAND(LL,J), J = 1,12)
      IF (TITLE.NE.LABEL(L).OR.NUM.NE.LL) GO TO 700
  150 CONTINUE
      L = 19
      DO 160 LL = 1,NTOWN
      READ (IN,1020) TITLE,NUM, ( RTURN(LL,J), J = 1,12)
      IF (TITLE.NE.LABEL(L).OR.NUM.NE.LL) GO TO 700
  160 CONTINUE
      L = 20
      LL = 0
      DO 170 M = 1,NTOWN,18
      LL = LL + 1
      N = M + 17
      IF (N.GT.NTOWN) N = NTOWN
      READ (IN,1020) TITLE,NUM, (MDCCAP(I),I = M,N)
      IF (TITLE.NE.LABEL(L).OR.NUM.NE.LL) GO TO 700
  170 CONTINUE
      L = 21
      DO 180 LL = 1, NTOWN
```

```
      READ (IN,1010) TITLE,NUM, (PRIORY(LL,J),J = 1,16)
      IF (TITLE.NE.LABEL(L).OR.NUM.NE.LL) GO TO 700
  180 CONTINUE
      L = 22
      LL = 0
      DO 195 I = 1,NTOWN
      DO 190 J = 1,10
      LL = LL + 1
      IF (LL.GE.100) LL = 0
      READ (IN,1020) TITLE,NUM, (WELCAP(I,J,K),K = 1,12)
      IF (TITLE.NE.LABEL(L).OR.NUM.NE.LL) GO TO 700
      IF (WELCAP(I,J,1).EQ.0.) GO TO 192
  190 CONTINUE
      GO TO 195
  192 DO 193 KK = J,10
      DO 193 K = 1,12
  193 WELCAP(I,KK,K) = 0.
  195 CONTINUE
      L = 23
      LL = 0
      DO 200 M = 1,NWELL,18
      LL = LL + 1
      N = M + 17
      IF (N.GT.NWELL) N = NWELL
      READ (IN,1020) TITLE,NUM, (WELPCT(I),I = M,N)
      IF (TITLE.NE.LABEL(L).OR.NUM.NE.LL) GO TO 700
  200 CONTINUE
      L = 24
      DO 210 LL = 1,NTOWN
      READ (IN,1010) TITLE,NUM, (WELL(LL,J),J = 1,10)
      IF (TITLE.NE.LABEL(L).OR.NUM.NE.LL) GO TO 700
  210 CONTINUE
      L = 25
      LL = 1
      READ (IN,1030) TITLE,NUM, (IMPMAX(I), I = 1,12)
      IF (TITLE.NE.LABEL(L)) GO TO 700
      L = 26
      READ (IN,1030) TITLE,NUM, (IMPMIN(I), I = 1,12)
      IF (TITLE.NE.LABEL(L)) GO TO 700
      L = 27
      READ (IN,1030) TITLE,NUM, (CLASS(I), I = 1,7)
      IF (TITLE.NE.LABEL(L)) GO TO 700
      L = 28
      READ (IN,1030) TITLE,NUM, TYMFAC
      IF (TITLE.NE.LABEL(L)) GO TO 700
      L = 29
      READ (IN,1030) TITLE,NUM, (DA(I),I = 1,NRCRDS)
      IF (TITLE.NE.LABEL(L)) GO TO 700
      DO 220 I = 1,NTOWN
      DO 220 K = 1,12
      GWMAX(I,K) = 0.
      DO 220 J = 1,10
  220 GWMAX(I,K) = GWMAX(I,K) + WELCAP(I,J,K)
      L = 30
      LL = 0
      DO 230 M = 1,NTOWN,18
      LL = LL + 1
      N = M + 17
      IF (N.GT.NTOWN) N = NTOWN
      READ (IN,1020) TITLE, NUM, (CONSUP(I),I=M,N)
      IF (TITLE.NE.LABEL(L).OR.NUM.NE.LL) GO TO 700
  230 CONTINUE
      L = 31
      DO 235 LL = 1,NWELL
      READ (IN,1030) TITLE, NUM, (UNIT(LL,I),I = 1,12)
      IF (TITLE.NE.LABEL(L).OR.NUM.NE.LL) GO TO 700
  235 CONTINUE
      L = 32
```

```
      LL = 0
      DO 236 M = 1,NNODE,24
      LL = LL + 1
      N = M + 23
      IF (N.GT.NNODE) N = NNODE
      READ (IN,1010) TITLE, NUM, (IDVRZN(I),I = M,N)
      IF (TITLE.NE.LABEL(L).OR. NUM.NE.LL) GO TO 700
  236 CONTINUE
      J = 0
  237 IMIN = NNODE
      DO 238 I = 1,NNODE
      IF (IDVRZN(I).GT.0.AND.IDVRZN(I).LT.IMIN) IMIN = I
  238 CONTINUE
      IF (IMIN.EQ.NNODE) GO TO 239
      J = J + 1
      IORDER(J) = IMIN
      IDVRZN(IMIN) = -IDVRZN(IMIN)
      GO TO 237
  239 DO 241 I = 1,NNODE
  241 IDVRZN(I) = -IDVRZN(I)
      DO 240 I = 1,NTOWN
      DO 240 J = 1,12
  240 DEMAND(I,J) = CONSUP(I)*DEMAND(I,J)/.83333
C
C        WITH PROPER OPTION CODE CALL THE ROUTINE 'LST' TO LIST THE
C             INPUT DATA.
C
      IF ((NPRINT/7)*7.EQ.NPRINT) CALL LST
      RETURN
  700 WRITE (OUT,2000) LL,LABEL(L)
      STOP
C
C
 1010 FORMAT (A4,2X,I2,24I3)
 1020 FORMAT (A4,2X,I2,18F4.3)
 1030 FORMAT (A4,2X,I2,12F6.1)
 1040 FORMAT (3A4)
 2000 FORMAT (10X,'*** CARD ',I3,' OF ',A4,' IS OUT OF ORDER ')
      END
```

……

```
      SUBROUTINE ROFLOW
C
C
C        DISTRIBUTES THE STREAMFLOW TO EACH SUBBASIN
C
C
      COMMON IITIME, ITIME, MAXCAP(60), NNODE, Q(60), STCAPY(60),
     1 TOWN(25), TYMFAC
      COMMON /M12/ DA(10), IMPMAX(12), IMPMIN(12), IMPNOD, IMPQ, IMPREC,
     1 IN, NRCRDS, NWELL, PERCNT(60,12), QQ(60), QSUBA(60), RECORD(60),
     2 RESDA(60), RESOOB(60), SUBADA(60), WELNOD(60), WELPCT(60)
      REAL IMPMAX, IMPMIN, IMPQ
      INTEGER RECORD, RESOOB, WELNOD
      REAL MAXCAP
      INTEGER TOWN
      DIMENSION DIS(10)
C
C
      READ (IN,1000) (DIS(I),I=1,NRCRDS)
C
C        COMPUTE THE AVERAGE RUNOFF FOR FOR ALL THE GAGING STATIONS USED
C
      RUNOFF = 0
      DO 10 I = 1,NRCRDS
   10 RUNOFF = RUNOFF + DIS(I)/DA(I)
      RUNOFF = RUNOFF*.646317/ FLOAT(NRCRDS)
C
```

```
C         DISTRIBUTE THE INCREMENTAL GAGED STREAMFLOW TO EACH SUBBASIN
C               AND PUT AVERAGE RUNOFF INTO EACH RESERVOIR.
C
      K = 1
      DO 20 INODE = 1,NNODE
      I = RECORD(INODE)
      IF(I.EQ.K) GO TO 15
      K = I
      L = I - 1
   12 DIS(I) = DIS(I) - DIS(L)
      L = L - 1
      IF (L.NE.0) GO TO 12
   15 QSUBA(INODE) = PERCNT(INODE,ITIME)*DIS(I)*.646317
      RESQ = 0
      IF (SUBADA(INODE).NE.0.) RESQ = (RESDA(INODE)/SUBADA(INODE))*QSUBA
     1(INODE)
      IF (RESOOB(INODE).NE.1) QSUBA(INODE) = QSUBA(INODE) - RESQ
      IF (RESOOB(INODE).EQ.1) RESQ = RUNOFF*RESDA(INODE)
       STCAPY(INODE) = STCAPY(INODE) + RESQ*TYMFAC
      IF (STCAPY(INODE).LE.MAXCAP(INODE)) GO TO 20
      IF (RESOOB(INODE).NE.1) QSUBA(INODE) = QSUBA(INODE) + (STCAPY(INOD
     1E) - MAXCAP(INODE))/ TYMFAC
      STCAPY(INODE) = MAXCAP(INODE)
   20 CONTINUE
      IMPQ = DIS(IMPREC)*.646317
      RETURN
C
C
 1000 FORMAT (10F8.0)
      END
```

```
      SUBROUTINE NATHYD
C
C
C         COMPUTES THE EFFECTS OF WELLS ON THE STREAMFLOW AND
C               ACCUMULATES THE STREAMFLOW OF EACH SUBBASIN IN THE RIVER.
C
C
      COMMON IITIME, ITIME, MAXCAP(60), NNODE, Q(60), STCAPY(60),
     1 TOWN(25), TYMFAC
      COMMON /M12/ DA(10), IMPMAX(12), IMPMIN(12), IMPNOD, IMPQ, IMPREC,
     1 IN, NRCRDS, NWELL, PERCNT(60,12), QQ(60), QSUBA(60), RECORD(60),
     2 RESDA(60), RESOOB(60), SUBADA(60), WELNOD(60), WELPCT(60)
      COMMON /S2356/ NPRINT, STMAX(60,12), SWMIN(60,12)
      COMMON /M24/ EFF(60,12), UNIT(60,12), WELL(25,10)
      COMMON /M568/ IDVRZN(60), IFILST(60), MAXMOC(25), NODNAM(63,3),
     1 OUT
      INTEGER OUT
      REAL IMPMAX, IMPMIN, IMPQ
      INTEGER RECORD, RESOOB, WELNOD
      INTEGER WELL
      REAL MAXCAP
      INTEGER TOWN
      DIMENSION IFTIME(4)
      DATA IFTIME /0,2,6,12 /
C
C
C         COMPUTE THE AMOUNT OF AN IMPORTED DISCHARGE AND AUGMENT THE
C               STREAMFLOW THAT AMOUNT  AT THE PROPER RIVER POINT
C
      QIMP =AMIN1(IMPMAX(ITIME),IMPQ-IMPMIN(ITIME))
      IF (QIMP.LT.0.) QIMP = 0.
      QQ(IMPNOD) = QIMP
      QIMP = QIMP *TYMFAC
C
C         WITH PROPER OPTION CODE PRINT THE AMOUNT OF IMPORTED WATER THAT
```

```
C                 AUGMENTS THE RIVER FLOW
C
      IF ((NPRINT/5)*5.EQ.NPRINT.AND.QIMP.NE.0.) WRITE (OUT,2000) QIMP ,
     1 IITIME
C
C         FOR WELLS AFFECTING A TRIBUTARY, SUBTRACT FROM A SUBBASIN'S
C              RUNOFF THE EFFECT OF WELL PUMPAGES AND THEN ACCUMULATE
C              THE RIVER DISCHARGE UP TO RIVER POINT 'I'
C
      I = 1
      IWELL = 1
   10 DO 50 INODE = I,NNODE
      IF (WELNOD(IWELL).NE.INODE) GO TO 40
      IF (WELPCT(IWELL).GT.1.) GO TO 60
      QDELTA = 0
      DELTAQ = QSUBA(INODE)*WELPCT(IWELL) - EFF(IWELL,1)
   20 IF (DELTAQ.LT.0.) EFF(IWELL,2) = EFF(IWELL,2) - DELTAQ
      DELTAQ =AMAX1(DELTAQ,0.)
      QDELTA = QDELTA + DELTAQ
      IWELL = IWELL + 1
      IF (WELNOD(IWELL).NE.INODE) GO TO 30
      DELTAQ = QSUBA(INODE)*(WELPCT(IWELL) - WELPCT(IWELL-1))
     1 - EFF(IWELL,1)
      GO TO 20
   30 QSUBA(INODE) = QSUBA(INODE)*(1. - WELPCT(IWELL-1)) + QDELTA
   40 IF (INODE.GT.1) GO TO 50
      Q(1) = QSUBA(1)
      GO TO 70
   50 Q(INODE) = Q(INODE-1) + QSUBA(INODE) + QQ(INODE)
      GO TO 75
C
C         FOR WELLS AFFECTING THE MAINSTREAM, ACCUMULATE THE RIVER DISCHARGE
C              UP TO RIVER POINT 'I' AND THEN SUBTRACT FROM THAT STREAMFLOW
C              THE EFFECT OF WELL PUMPAGES.
C
   60 Q(INODE) = Q(INODE-1) + QSUBA(INODE) + QQ(INODE)
      DELTAQ = Q(INODE) - EFF(IWELL,1)
      IF (DELTAQ.LT.0.) EFF(IWELL,2) = EFF(IWELL,2) - DELTAQ
      Q(INODE) =AMAX1(DELTAQ,0.)
      IWELL = IWELL + 1
   70 I = INODE + 1
      IF (I.LE.NNODE) GO TO 10
C
C         IN THE SPRING MONTHS REDUCE THE WELL EFFECT HYDROGRAPHS TO ZERO
C              AND SUBTRACT THAT AMOUNT FROM THE STREAMFLOW AT EACH
C              RESPECTIVE RIVER POINT.
C
   75 IF (ITIME.EQ.1.OR.ITIME.GT.4) RETURN
      L = IFTIME(ITIME)
      DO 130 IWELL = 1,NWELL
      INODE = WELNOD(IWELL)
      IF (WELPCT(IWELL).GT.1.) GO TO 100
      DO 90 I = 1,L
      IF ((QSUBA(INODE)*WELPCT(IWELL)/2.).LE.EFF(IWELL,I)) GO TO 130
      QSUBA(INODE) = QSUBA(INODE) - EFF(IWELL,I)
      DO 80 K = INODE,NNODE
   80 Q(K) = Q(K) - EFF(IWELL,I)
   90 EFF(IWELL,I) = 0
      GO TO 130
  100 DO 120 I = 1,L
      IF ((Q(INODE)/2.).LE.EFF(IWELL,I)) GO TO 130
      DO 110 K = INODE,NNODE
  110 Q(K) = Q(K) - EFF(IWELL,I)
  120 EFF(IWELL,I) = 0
  130 CONTINUE
      RETURN
C
C
 2000 FORMAT (30X,F7.1,' MG WAS IMPORTED INTO THE BASIN IN MONTH NUMBER
     1',I3)
      END
```

```
      SUBROUTINE LOCAL
C
C
C        DRAWS WATER FROM FIRST SET OF SUPPLY SOURCES.
C
C
      COMMON IITIME, ITIME, MAXCAP(60), NNODE, Q(60), STCAPY(60),
     1 TOWN(25), TYMFAC
      COMMON /M35/ DEFICT(25), DEMAND(25,12), GWMAX(25,12), IFLAG,
     1 IPRELM, IRTURN(25), MDCCAP(25), NTIME, NTOWN, PRIORY(25,16),
     2 RTURN(25,12), SWMAX(25,12), WELCAP(25,10,12)
      COMMON /S2356/ NPRINT, STMAX(60,12), SWMIN(60,12)
      REAL MAXCAP
      INTEGER TOWN
      REAL MDCCAP
      INTEGER PRIORY
C
C
      DO 100 ITOWN = 1,NTOWN
      INODE = TOWN(ITOWN)
      SUPPLY = 0
C
C        GO TO THE SOURCE OF THE HIGHEST PRIORITY.
C
      DO 70 K = 1,8
      L = PRIORY(ITOWN,K) + 1
      IF (L.LE.3) GO TO (10,20,30), L
C
C              TAKE WATER FROM A RESERVOIR
C
      ISTORE = L - 11
      STUSED = AMIN1(STMAX(ISTORE,ITIME),STCAPY(ISTORE)/TYMFAC, DEMAND(I
     1TOWN,ITIME) - SUPPLY)
      STCAPY(ISTORE) = STCAPY(ISTORE) - STUSED*TYMFAC
      SUPPLY = SUPPLY + STUSED
      GO TO 60
C
C              NO OTHER SOURCES FROM THE FIRST SET, SO DEFINE A
C                   TEMPORARY DEFICIT.
C
   10 DEFICT(ITOWN) = DEMAND(ITOWN,ITIME) - SUPPLY
      IFLAG = IFLAG + 1
      GO TO 80
C
C              TAKE WATER FROM WELLS
C
   20 RATE = (DEMAND(ITOWN,ITIME) - SUPPLY)/GWMAX(ITOWN,ITIME)
      IF (RATE.GT.1.) RATE = 1.
      DO 25 I = 1,10
      GWUSED = RATE*WELCAP(ITOWN,I,ITIME)
      IF (GWUSED.NE.0.) CALL EFFECT(GWUSED,I,ITOWN)
   25 SUPPLY = SUPPLY + GWUSED
      GO TO 60
C
C              TAKE WATER FROM A STREAMFLOW DIVERSION
C
   30 SWUSED = AMIN1(SWMAX(ITOWN,ITIME),Q(INODE) - SWMIN(INODE,ITIME),
     1 DEMAND(ITOWN,ITIME) - SUPPLY)
      IF (SWUSED.LT.0.) SWUSED = 0.
      DO 40 I= INODE,NNODE
   40 Q(I) = Q(I) - SWUSED
      SUPPLY = SUPPLY + SWUSED
   60 IF (DEMAND(ITOWN,ITIME).GE.(SUPPLY -.0001*SUPPLY).AND.DEMAND(ITOWN
     1,ITIME).LE.(SUPPLY + .0001*SUPPLY)) GO TO 75
   70 CONTINUE
   75 DEFICT(ITOWN) = 0.
C
C        RETURN USED WATER TO STREAMFLOW ACCORDING TO A SEWAGE FUNCTION.
```

```
C
   80 ADD = RTURN(ITOWN,ITIME)*SUPPLY
      J = IRTURN(ITOWN)
      DO 90 I = J,NNODE
   90 Q(I) = Q(I) + ADD
  100 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE EFFECT(GWUSED,I,ITOWN)
C
C
C         ACCUMULATES THE EFFECTS OF WELL PUMPAGES ACCORDING TO A UNIT
C               FUNCTION FOR EACH WELL.
C
C
      COMMON IITIME, ITIME, MAXCAP(60), NNODE, Q(60), STCAPY(60),
     1 TOWN(25), TYMFAC
      COMMON /M24/ EFF(60,12), UNIT(60,12), WELL(25,10)
      INTEGER TOWN
      INTEGER WELL
      REAL MAXCAP
C
C
      IWELL = WELL(ITOWN,I)
      DO 10 J = 1,11
   10 EFF(IWELL,J) = EFF(IWELL,J+1) + UNIT(IWELL,J)*GWUSED
      RETURN
      END
```

```
      SUBROUTINE REGION
C
C
C         DRAWS WATER FROM A SECOND SET OF SUPPLY SOURCES.
C
C
      COMMON IITIME, ITIME, MAXCAP(60), NNODE, Q(60), STCAPY(60),
     1 TOWN(25), TYMFAC
      COMMON /M35/ DEFICT(25), DEMAND(25,12), GWMAX(25,12), IFLAG,
     1 IPRELM, IRTURN(25), MDCCAP(25), NTIME, NTOWN, PRIORY(25,16),
     2 RTURN(25,12), SWMAX(25,12), WELCAP(25,10,12)
      COMMON /M568/ IDVRZN(60), IFILST(60), MAXMDC(25), NODNAM(63,3),
     1 OUT, SWSMAX(60,12), TTLDF(25), TTLDV(60), TTLMDC(25), IORDER(60)
      COMMON /S2356/ NPRINT, STMAX(60,12), SWMIN(60,12)
      REAL MAXCAP,MDCUSE
      INTEGER TOWN
      REAL MDCCAP
      INTEGER PRIORY
      REAL MAXMDC
      INTEGER OUT
C
C
      DO 70 ITOWN = 1,NTOWN
      IF (DEFICT(ITOWN).EQ.0.) GO TO 70
      INODE = TOWN(ITOWN) - 1
C
C         GO TO THE SOURCE OF THE HIGHEST PRIORITY.
C
```

```
      DO 50 K = 9,16
      L = PRIORY(ITOWN,K) + 1
      IF (L.LE.3) GO TO (60,10,20), L
C
C              TAKE WATER FROM A RESERVOIR
C
      ISTORE = L - 11
      STUSED = AMIN1(STMAX(ISTORE,ITIME),STCAPY(ISTORE)/TYMFAC,DEFICT(IT
     1OWN))
      STCAPY(ISTORE) = STCAPY(ISTORE) - STUSED*TYMFAC
      DEFICT(ITOWN) = DEFICT(ITOWN) - STUSED
      SUPPLY = STUSED
      GO TO 40
C
C              TAKE WATER FROM SOME EXTERNAL SOURCE
C
   10 MDCUSE =AMIN1(MDCCAP(ITOWN),DEFICT(ITOWN))
      DEFICT(ITOWN) = DEFICT(ITOWN) - MDCUSE
      SUPPLY = MDCUSE
      MDCUSE = MDCUSE * TYMFAC
      TTLMDC(ITOWN) = TTLMDC(ITOWN) + MDCUSE
      MAXMDC(ITOWN) =AMAX1(MAXMDC(ITOWN),MDCUSE)
      GO TO 40
C
C              TAKE WATER FROM WELLS
      MAXMDC(ITOWN) =AMAX1(MAXMDC(ITOWN),MDCUSE)
      GO TO 40
C
C              TAKE WATER FROM WELLS
C
   20 RATE = DEFICT(ITOWN)/GWMAX(ITOWN,ITIME)
      SUPPLY = 0
      IF (RATE.GT.1.) RATE = 1.
      DO 25 I = 1,10
      GWUSED = RATE*WELCAP(ITOWN,I,ITIME)
      IF (GWUSED.NE.0.) CALL EFFECT(GWUSED,I,ITOWN)
   25 SUPPLY = SUPPLY + GWUSED
      DEFICT(ITOWN) = DEFICT(ITOWN) - SUPPLY
C
C         RETURN USED WATER TO STREAMFLOW ACCORDING TO A SEWAGE FUNCTION.
C
   40 ADD = RTURN(ITOWN,ITIME)*SUPPLY
      J = IRTURN(ITOWN)
      DO 45 I = J,NNODE
   45 Q(I) = Q(I) + ADD
      IF (DEFICT(ITOWN).GT.-.0001.AND.DEFICT(ITOWN).LT..0001) DEFICT(ITO
     1WN) = 0.
      IF (DEFICT(ITOWN).EQ.0.) IFLAG = IFLAG - 1
      IF (IFLAG.EQ.0) RETURN
      IF(DEFICT(ITOWN).EQ.0.) GO TO 70
   50 CONTINUE
C
C         PRINT OUT A DEFICIT INCURRED BY ANY TOWN AND THEN ACCUMULATE IT
C
   60 WRITE (OUT,2000) (NODNAM(INODE+1,LL),LL= 1,3),DEFICT(ITOWN),IITIME
      TTLDF (ITOWN) = TTLDF(ITOWN) + DEFICT(ITOWN)*TYMFAC
      DEFICT(ITOWN) = 0
      IFLAG = IFLAG - 1
      IF (IFLAG.EQ.0) RETURN
   70 CONTINUE
      RETURN
C
C
 2000 FORMAT (10X,3A4,' HAD A DEFICIT OF ',F8.4,' MGD IN MONTH NUMBER '
     1,I3)
      END
```

```
      SUBROUTINE FILLST
C
C
C          REGULATES THE TRANSFER OF WATER TO AND FROM RESERVOIRS
C
C
      COMMON IITIME, ITIME, MAXCAP(60), NNODE, Q(60), STCAPY(60),
     1 TOWN(25), TYMFAC
      COMMON /M568/ IDVRZN(60), IFILST(60), MAXMDC(25), NODNAM(63,3),
     1 OUT, SWSMAX(60,12), TTLDF(25), TTLDV(60), TTLMDC(25), IORDER(60)
      COMMON /S2356/ NPRINT, STMAX(60,12), SWMIN(60,12)
      REAL MAXCAP
      INTEGER TOWN
      REAL MAXMDC
      INTEGER OUT
C
C
C          DIVERT WATER FROM THE RIVER TO A RESERVOIR.
C
      DO 20 JJ = 1,NNODE
      IF (IORDER(JJ).EQ.0) GO TO 20
      INODE = IORDER(JJ)
      I = IDVRZN(INODE)
      DIVERT = AMIN1((MAXCAP(INODE) - STCAPY(INODE))/TYMFAC,SWSMAX(INODE
     1,ITIME), Q(I) - SWMIN(I,ITIME))
      IF (DIVERT.LE.0.) GO TO 20
      X = DIVERT * TYMFAC
      STCAPY(INODE) = STCAPY(INODE) + X
C
C          WITH PROPER OPTION CODE PRINT THE AMOUNT OF WATER DIVERTED
C                FROM THE RIVER
C
      IF ((NPRINT/2)*2.EQ.NPRINT) WRITE(OUT,2000) (NODNAM(INODE,LL) , LL
     1 = 1,3) , X , IITIME
C
C          REMOVE THE DIVERSION FROM THE STREAMFLOW AND ACCUMULATE THE
C                DIVERSIONS
C
      TTLDV(INODE) = TTLDV(INODE) + X
      DO 10 J = I,NNODE
   10 Q(J) = Q(J) - DIVERT
   20 CONTINUE
C
C          TRANSFER WATER FROM ONE RESERVOIR TO ANOTHER
C
      DO 30 INODE = 1,NNODE
      IF (IFILST(INODE).EQ.0) GO TO 30
      I = IFILST(INODE)
      XCHANG = AMIN1(STMAX(INODE,ITIME)*TYMFAC,STCAPY(INODE),MAXCAP(I)-
     1STCAPY(I))
      STCAPY(INODE) = STCAPY(INODE) - XCHANG
      STCAPY(I) = STCAPY(I) + XCHANG
C
C          WITH THE PROPER OPTION CODE PRINT THE AMOUNT OF WATER THAT WAS
C                TRANSFERRED FROM ONE RESERVOIR TO ANOTHER
C
      IF ((NPRINT/3)*3.EQ.NPRINT) WRITE (OUT,2010) XCHANG, (NODNAM(INODE
     1,LL),LL=1,3),(NODNAM(I,LL),LL=1,3),IITIME
   30 CONTINUE
      RETURN
C
C
 2000 FORMAT (81X,3A4,' DIVERTED ',F6.1,' MG IN MONTH NUMBER ',I3)
 2010 FORMAT (54X,F7.1,' MG WAS DIVERTED FROM ',3A4,' TO ',3A4,' IN MONT
     1H NUMBER ',I3)
      END
```

```
      SUBROUTINE KEPTRK
C
C
C        KEEPS TRACK OF CERTAIN STATISTICS ON A MONTHLY BASIS
C
C
      COMMON IITIME, ITIME, MAXCAP(60), NNODE, Q(60), STCAPY(60),
     1 TOWN(25), TYMFAC
      COMMON /M78/ CLASS(7), FREQ(10,8), MAXST(60), MINST(60), NOBS,
     1 OBS(10), OBSMAX(10), OBSMIN(10)
      COMMON /R2/ ITRZFL, ITRZST, QTRACE(120,9), FLTRAZ(120,9), IWANTX
      REAL MAXCAP
      INTEGER TOWN
      REAL MAXST, MINST
      INTEGER OBS
C
C
      DO 20 IOBS = 1,NOBS
      INODE = OBS(IOBS)
      IF (ITRZFL.NE.0) QTRACE(IITIME,IOBS) = Q(INODE)
      IF (ITRZST.NE.0) FLTRAZ(IITIME,IOBS) = STCAPY(INODE)
      OBSMAX(IOBS) =AMAX1(OBSMAX(IOBS),Q(INODE))
      OBSMIN(IOBS) =AMIN1(OBSMIN(IOBS),Q(INODE))
      DO 10 I = 1,7
      IF (Q(INODE).LT.CLASS(I)) GO TO 20
   10 CONTINUE
      I = 8
   20 FREQ(IOBS,I) = FREQ(IOBS,I) + 1.
      IF (IWANTX.NE.0) CALL WANTX1
      DO 30 INODE = 1,NNODE
      MAXST(INODE) =AMAX1(MAXST(INODE),STCAPY(INODE))
   30 MINST(INODE) =AMIN1(MINST(INODE),STCAPY(INODE))
      RETURN
      END
-----------------------------------------------------------------------------------------------------------------
      SUBROUTINE APRINT
C
C
C        PRINTS ALL OF THE SUMMARY RESULTS
C
C
      COMMON IITIME, ITIME, MAXCAP(60), NNODE, Q(60), STCAPY(60),
     1 TOWN(25), TYMFAC
      COMMON /M78/ CLASS(7), FREQ(10,8), MAXST(60), MINST(60), NOBS,
     1 OBS(10), OBSMAX(10), OBSMIN(10)
      COMMON /M568/ IDVRZN(60), IFILST(60), MAXMDC(25), NODNAM(63,3),
     1 OUT, SWSMAX(60,12), TTLDF(25), TTLDV(60), TTLMDC(25), IORDER(60)
      COMMON /M35/ DEFICT(25), DEMAND(25,12), GWMAX(25,12), IFLAG,
     1 IPRELM, IRTURN(25), MDCCAP(25), NTIME, NTOWN, PRIORY(25,16),
     2 RTURN(25,12), SWMAX(25,12), WELCAP(25,10,12)
      COMMON /M12/ DA(10), IMPMAX(12), IMPMIN(12), IMPNOD, IMPQ, IMPREC,
     1 IN, NRCRDS, NWELL, PERCNT(60,12), QQ(60), QSUBA(60), RECORD(60),
     2 RESDA(60), RESOOB(60), SUBADA(60), WELNOD(60), WELPCT(60)
      COMMON /R2/ ITRZFL, ITRZST, QTRACE(120,9), FLTRAZ(120,9), IWANTX
      DIMENSION ITITLE(4), DUMMY(120), NODE(4)
      DIMENSION IVAR(4)
      DATA N1, N2, N3 / 4HFLOW,4HSTOR,4H     /
      REAL MDCCAP,IMPMAX,IMPMIN,IMPQ
      INTEGER PRIORY, RECORD, RESOOB,WELNOD
      REAL MAXCAP
      INTEGER TOWN
      REAL MAXST, MINST
      INTEGER OBS
      REAL MAXMDC
      INTEGER OUT
      INTEGER FORMT(10),FRMAT(4),FRMATT(4)
C
```

```
C         IGNORE COMPILER WARNINGS
C
      DATA IVAR / 16HA   B   C   D    /
                                      $
 IEY038I SIZE WRN.************************************************************
      DATA FRMAT /16H(1H+    X,3A4)    /
                                      $
 IEY038I SIZE WRN.************************************************************
      DATA FRMATT /16H(1H+    X,F9.2)   /
                                       $
 IEY038I SIZE WRN.************************************************************
      DATA FORMT / 40H,  1, 14, 27,040, 53, 66, 79, 92,105,118   /
                                                                $
 IEY038I SIZE WRN.************************************************************
C
C
C         PRINT A HYCROLOGICAL SUMMARY SHEET FOR EACH RIVER POINT DESIRED
C              WITH A FREQUENCY TABLE
C
      WRITE (OUT,2000) (CLASS(I),I = 1,7)
      DC 3C I = 1,NOBS
      TCTAL = 0
      DC 10 J = 1,8
   10 TOTAL = TCTAL + FREQ(I,J)
      DC 20 J = 1,8
   20 FREQ(I,J) = FREQ(I,J)/TCTAL
      LL = CBS(I)
   30 WRITE (OUT,2010) (NODNAM(LL,LLL),LLL=1,3) ,OBSMAX(I) ,OBSMIN(I) ,
     1(FREQ(I,J),J= 1,8)
      WRITE (OUT, 2020)
      L = 1
C
C         PRINT THE PRIMARY SUMMARY SHEET
C
      DC 5C I = 1,NNCDE
      IF (TCWN(L).NE.I) GO TO 40
      WRITE (OUT,2030) (NODNAM(I,LL),LL= 1,3) ,MAXCAP(I), MAXST(I) ,MINS
     1T(I), TTLDV(I), TTLMDC(L), MAXMDC(L), TTLDF(L)
      L = L + 1
      GC TO 50
   40 WRITE (OUT,2030) (NCDNAM(I,LL),LL= 1,3) ,MAXCAP(I), MAXST(I) ,MINS
     1T(I), TTLDV(I)
   50 CCNTINUE
C
C         WITH PROPER OPTION CODE PRINT A FLCW TRACE AT ANY RIVER PCINT
C              DESIRED
C
      IF (ITRZFL.LE.1) GO TC 90
      WRITE (OUT,2040)
      DO  60 I = 1,NOBS
      J = CBS(I)
      FRMAT(2) = FCRMT(I+1)
   60 WRITE (OUT,FRMAT) (NODNAM(J,K),K=1,3)
      DC 70 I = 1,NTIME
      WRITE (OUT,2050) I
      DO  7C J = 1,NOBS
      FRMATT(2) = FORMT(J+1)
   70 WRITE (OUT,FRMATT) QTRACE(I,J)
C
C         WITH PROPER OPTION CODE PRINT A STORAGE TRACE FOR ANY RIVER
C              PCINT DESIRED
C
   90 IF (ITRZST.LE.1) GO TO 125
      WRITE (OUT,2060)
      DO 100 I = 1,NOBS
      J = CBS(I)
      FRMAT(2) = FORMT(I+1)
  100 WRITE (OUT,FRMAT) (NODNAM(J,K),K=1,3)
```

```
      DO 110 I = 1,NTIME
      WRITE (OUT,2050) I
      DO 110 J = 1,NOBS
      FRMATT(2) = FORMT(J+1)
  110 WRITE (OUT,FRMATT) FLTRAZ(I,J)
C
C        WITH PROPER OPTION CODE CALL THE SPECIAL PLOT ROUTINE 'WANTX'
C
  125 IF (IWANTX.NE.0) CALL WANTX
C
C        WITH PROPER OPTION CODE PLOT A HYDROGRAPH OF ANY FLOW TRACE
C             OR STORAGE TRACE DESIRED.
C
      IF (ITRZFL.EQ.0.AND.ITRZST.EQ.0) RETURN
  130 READ (IN,1000) (ITITLE(I),NODE(I),I= 1,4)
      DO 300 I = 1,120
  300 DUMMY(I) = 0
      J = 1
      DO 140 I = 1,4
      IF (ITITLE(I).EQ.N1) J = J*2
      IF (ITITLE(I).EQ.N2) J = J*3
      IF (ITITLE(I).EQ.N3) GO TO 150
  140 CONTINUE
      I = 5
  150 NUM = I - 1
      IF (NUM.EQ.0) RETURN
      DO 160 I = 1,NOBS
      IF (NODE(1).EQ.OBS(I)) J1 = I
      IF (NODE(2).EQ.OBS(I)) J2 = I
      IF (NODE(3).EQ.OBS(I)) J3 = I
      IF (NODE(4).EQ.OBS(I)) J4 = I
  160 CONTINUE
      WRITE (OUT,2070)
      DO  170 I = 1,NUM
      L = NODE(I)
  170 WRITE (OUT,2080) IVAR(I), ITITLE(I), (NODNAM(L,LL),LL= 1,3)
      WRITE (OUT,2090)
C
C             CALL PLOT ROUTINE 'PLOTER' WITH THE DESIRED PARAMETERS
C
      IF ((J/6)*6.EQ.J) GO TO (130,260,130,270),NUM
      IF ((J/3)*3.EQ.J) GO TO (220,230,240,250), NUM
      GO TO (180,190,200,210), NUM
  180 CALL PLOTER(QTRACE(1,J1),DUMMY,DUMMY,DUMMY)
      GO TO 130
  190 CALL PLOTER(QTRACE(1,J1),QTRACE(1,J2),DUMMY,DUMMY)
      GO TO 130
  200 CALL PLOTER(QTRACE(1,J1),QTRACE(1,J2),QTRACE(1,J3),DUMMY)
      GO TO 130
  210 CALL PLOTER(QTRACE(1,J1),QTRACE(1,J2),QTRACE(1,J3),QTRACE(1,J4))
      GO TO 130
  220 CALL PLOTER (FLTRAZ(1,J1),DUMMY,DUMMY,DUMMY)
      GO TO 130
  230 CALL PLOTER (FLTRAZ(1,J1),FLTRAZ(1,J2),DUMMY,DUMMY)
      GO TO 130
  240 CALL PLOTER (FLTRAZ(1,J1),FLTRAZ(1,J2),FLTRAZ(1,J3),DUMMY)
      GO TO 130
  250 CALL PLOTER (FLTRAZ(1,J1),FLTRAZ(1,J2),FLTRAZ(1,J3),FLTRAZ(1,J4))
      GO TO 130
  260 CALL PLOTER(QTRACE(1,J1),FLTRAZ(1,J2),DUMMY,DUMMY)
      GO TO 130
  270 CALL PLOTER(QTRACE(1,J1),FLTRAZ(1,J2),QTRACE(1,J3),FLTRAZ(1,J4))
      GO TO 130
C
C
 1000 FORMAT (4(A4,I2))
 2000  FORMAT (1H1/// 4X, 'OBSERVATION NODE',3X,'MAX MONTHLY FLOW',3X,'M
     1IN MONTHLY FLOW',25X,'FREQUENCY TABLE  (MGD)' / 28X,'(MGD)',14X,'(
```

```
     2MGD)',7X'0.',7(' <Q< ',F4.0), ' <Q' )
 2010 FORMAT (6X,3A4,7X,F8.0,13X,F6.2,6X,8(4X,F5.3))
 2020 FORMAT (1H1/// 2X,'RIVER POINT',3X,'STORAGE CAPACITY',2X,'MAX STOR
     1AGE',2X,'MIN STORAGE',2X,'FLOW DIVERTED',2X,'WATER PURCHASED',2X,'
     2MAX MONTHLY PURCHASE',2X,'TOTAL DEFICIT'  /  22X,'(MG)',12X,'(MG)'
     3,9X,'(MG)',9X,'(MG)',13X,'(MG)',15X,'(MG)',14X,'(MG)'  )
 2030 FORMAT (2X,3A4,6X,F6.0,10X,F6.0,7X,F6.0,5X,F8.0,11X,F7.1,13X,F6.1,
     110X,F7.0)
 2040 FORMAT (1H1//,40X,'FLOW TRACE AT INDICATED POINT   (MGD)' //5X,
     1 'MONTH')
 2050 FORMAT (/,6X,I3)
 2060 FORMAT (1H1//,30X,'RESERVOIR STORAGE TRACE AT INDICATED POINT   (M
     1G)'  //5X, 'MONTH' )
 2070 FORMAT (1H1 //// 10X,'A PLOT FOR THE PERIOD OF RECORD' //20X,'IF M
     1ORE THAN ONE SCALE APPEARS, THE FIRST IS FOR SYMBOLS A AND C' /
     2 20X, 'AND THE INNER IS FOR SYMBOLS B AND D.  '///30X'X REPRESENTS
     3 MORE THAN ONE VARIABLE AT A POINT'  )
 2080 FORMAT (30X,A1,' REPRESENTS ',A4,' FOR ' ,3A4)
 2090 FORMAT (////)
      END
```

```
      SUBROUTINE PLOTER (A,B,C,D)
C
C
C         PLOTS A TIME SERIES
C
C
      COMMON /M568/ IDVRZN(60), IFILST(60), MAXMDC(25), NODNAM(63,3),
     1 OUT
      COMMON /M35/ DEFICT(25), DEMAND(25,12), GWMAX(25,12), IFLAG,
     1 IPRELM, IRTURN(25), MDCCAP(25), NTIME
      DIMENSION A(120), B(120), C(120), D(120), DUMMY1(1), X(13), DUMMY2
     1(1), Y(13), DELTA(2), RANGE(2), SCALE(2,13), IDUMMY(1), LINE(125)
      DIMENSION MONTH(11)
      DATA MONTH /4HJAN ,4HFEB ,4HMAR ,4HAPR ,4HMAY ,4HJUNE,4HJULY,4HAUG
     1 ,4HSEPT,4HOCT ,4HNOV  /
      DATA DUMMY1, X, DUMMY2, Y / 40000.,20000.,18750.,12500.,6250.,
     13125.,2500.,1875.,1250.,625.,500.,250.,125.,0.,400.,200.,150.,100.
     2, 50.,25.,20.,15.,10.,5.,4.,2.,1.,0.  /
      DATA IA,IB,IC,ID,IX,II,IBLANK /1HA,1HB,1HC,1HD,1HX,1HI,1H /
      INTEGER OUT
C
C
C         FIND MAXIMUM VALUE OF EACH SERIES
C
      AAMAX = 0
      BMAX = 0
      CMAX = 0
      DMAX = 0
      DO 10 I = 1,NTIME
      IF (A(I).GT.AAMAX) AAMAX = A(I)
      IF (B(I).GT. BMAX)  BMAX = B(I)
      IF (C(I).GT. CMAX)  CMAX = C(I)
      IF (D(I).GT. DMAX)  DMAX = D(I)
   10 CONTINUE
C
C         COMPUTE SCALE FACTORS
C
      RANGE(1) = IFIX(AMAX1(AAMAX,CMAX) + .999)
      RANGE(2) = IFIX(AMAX1( BMAX,DMAX) + .999)
      DO 30 I = 1,2
      DO 20 J = 1,12
      IF (RANGE(I).GT.X(J)) GO TO 30
   20 CONTINUE
      J = 13
   30 DELTA(I) = Y(J-1)
```

```
      K = 0
      IF (DELTA(1).LE.Y(J-2).AND.DELTA(1).GE.Y(J)) K = 1
      IF (K.EQ.0) GO TO 40
      DELTA(1) =AMAX1(DELTA(1),DELTA(2))
      DELTA(2) = DELTA(1)
   40 DO 60 I = 1,2
      SCALE(I,1) = 0
      SCALE(I,13) = DELTA(I)*125.
      DO 50 J = 2,12
   50 SCALE(I,J) = DELTA(I)*10.*FLOAT(J-1)
   60 WRITE (OUT,2000) (SCALE(I,J),J=1,13)
      WRITE (OUT,2010)
      WRITE (OUT,2040)
C
C         PLOT EACH OF FOUR POSSIBLE TIME SERIES EACH MONTH
C
      DO 150 I = 1,NTIME
      I2 = 0
      I3 = 0
      I4 = 0
      J = 0
      LINE(J) = IBLANK
      DO 70  J = 1,125
   70 LINE(J) = IBLANK
      I1 = A(I)/DELTA(1) + 1.5
      IF (BMAX.NE.0) I2 = B(I)/DELTA(2) +1.5
      IF (CMAX.NE.0) I3 = C(I)/DELTA(1) +1.5
      IF (DMAX.NE.0) I4 = D(I)/DELTA(2) +1.5
      LINE(I1) = IA
      IF (LINE(I2).NE.IBLANK) GO TO 100
      LINE(I2) = IB
   80 IF (LINE(I3).NE.IBLANK) GO TO 110
      LINE(I3) = IC
   90 IF (LINE(I4).NE.IBLANK) GO TO 120
      LINE(I4) = ID
      GO TO 130
  100 LINE(I2) = IX
      GO TO 80
  110 LINE(I3) = IX
      GO TO  90
  120 LINE(I4) = IX
  130 IF (LINE(1).EQ.IBLANK) LINE(1) = II
      IF (LINE(125).EQ.IBLANK) LINE(125) = II
      WRITE (OUT,2050)
      L = I - (I/12)*12
      IF (L.EQ.0) GO TO 140
      WRITE (OUT,2020) MONTH(L),(LINE(J),J=1,125)
      GO TO 150
  140 WRITE (OUT,2030) I,(LINE(J),J=1,125)
  150 CONTINUE
      WRITE (OUT,2040)
      WRITE (OUT,2010)
      WRITE (OUT,2000) (SCALE(2,J),J=1,13)
      WRITE (OUT,2000) (SCALE(1,J),J=1,13)
      RETURN
C
C
 2000 FORMAT (     3X,12(F6.0,4X),3X,F6.0)
 2010 FORMAT (7X,12('*',9X),4X,'*')
 2020 FORMAT (4X,A3,125A1)
 2030 FORMAT (4X,I3,125A1)
 2040 FORMAT (7X,1HI,123(1H*),1HI)
 2050 FORMAT (7X,1HI,123X,1HI)
      END
```

```
      SUBROUTINE LST
C
C
C        PRINTS A LIST OF THE INPUT DATA
C
C
      COMMON IITIME, ITIME, MAXCAP(60), NNODE, Q(60), STCAPY(60),
     1 TOWN(25), TYMFAC
      COMMON /M35/ DEFICT(25), DEMAND(25,12), GWMAX(25,12), IFLAG,
     1 IPRELM, IRTURN(25), MDCCAP(25), NTIME, NTOWN, PRIORY(25,16),
     2 RTURN(25,12), SWMAX(25,12), WELCAP(25,10,12)
      COMMON /M568/ IDVRZN(60), IFILST(60), MAXMDC(25), NODNAM(63,3),
     1 OUT, SWSMAX(60,12), TTLDF(25), TTLDV(60), TTLMDC(25), IORDER(60)
      COMMON /M24/ EFF(60,12), UNIT(60,12), WELL(25,10)
      COMMON /S2356/ NPRINT, STMAX(60,12), SWMIN(60,12)
      REAL MDCCAP
      INTEGER PRIORY
      INTEGER OUT
      INTEGER WELL
      INTEGER TOWN, TITLE
C
C
      WRITE (OUT,2050)
      IRES = 0
      DO 80 I = 1,NTOWN
      J = TOWN(I)
      WRITE (OUT,2000) (NODNAM(J,K),K=1,3)
      KOUNT = 1
      GO TO 90
C
C        PRINT THE SOURCES FOR EACH TOWN
C
    5 DO 57 J = 1,8
      L = PRIORY(I,J)
      IF (L.EQ.0) GO TO 60
      IF (L-2) 10,30,40
C
C               PRINT THE CAPACITY OF A WELL
C
   10 DO 20 M = 1,10
      IF (WELL(I,M).EQ.0) GO TO 57
      WRITE (OUT,2010) WELL(I,M),WELCAP(I,M,1)
      KOUNT = 2
      GO TO 90
   15 CONTINUE
   20 CONTINUE
      GO TO 57
C
C               PRINT THE CAPACITY OF A STREAM DIVERSION
C
   30 WRITE (OUT,2020) SWMAX(I,1)
      GO TO 50
C
C               PRINT THE YIELD CAPACITY OF A RESERVOIR
C
   40 K = L - 10
      WRITE (OUT,2030) (NODNAM(K,KK),KK = 1,3),STMAX(K,1)
   50 KOUNT = 3
      GO TO 90
   53 CONTINUE
   57 CONTINUE
   60 J = J + 1
      IF (J.GT.16) GO TO 80
      L = PRIORY(I,J)
      IF (L.EQ.0) GO TO 60
      IF (L - 2) 70,10,40
C
C               PRINT THE CAPACITY OF A CONNECTION TO AN EXTERNAL SOURCE
```

```
C
   70 WRITE (OUT,2040) MDCCAP(I)
      KOUNT = 4
   90 IRES = IRES  + 1
      IF (IRES.GT.NNODE) GO TO (5,15,53,60),KOUNT
C
C         PRINT EACH RESERVOIR INVOLVED IN TRANSFER OF WATER AND THE
C              CAPACITY OF THE PUMP OR PIPELINE THAT TRANSFERS THE WATER
C
      ID = IDVRZN(IRES)
      IFIL = IFILST(IRES)
      IF (ID.EQ.0) GO TO 120
      IF (IFIL.EQ.0) GO TO 100
      WRITE (OUT,2070) (NODNAM(IRES,KK),KK=1,3),(NODNAM(ID,KK),KK=1,3),
     1 SWSMAX(IRES,1),(NODNAM(IFIL,KK),KK=1,3),STMAX(IRES,1)
      GO TO 130
  100 WRITE (OUT,2080) (NODNAM(IRES,KK),KK=1,3),(NODNAM(ID,KK),KK=1,3),
     1 SWSMAX(IRES,1)
      GO TO 130
  120 IF (IFIL.EQ.0) GO TO 90
      WRITE (OUT,2090) (NODNAM(IRES,KK),KK=1,3),(NODNAM(IFIL,KK),KK=1,3)
     1 , STMAX(IRES,1)
  130 GO TO (5,15,53,60),KOUNT
   80 CONTINUE
      WRITE (OUT,2060)
      RETURN
C
C
 2000 FORMAT ( 1X,3A4)
 2010 FORMAT (16X,'WELL NUMBER ',I2,3X,F6.2)
 2020 FORMAT (16X,'STREAM DIVERSION ',F6.2)
 2030 FORMAT (16X,3A4,5X,F6.2)
 2040 FORMAT (16X,'TREATED IMPORT ',2X,F6.2)
 2050 FORMAT (///// 4X,'LIST OF TOWNS WATER RESOURCE SUPPLIES',15X,'LIST
     1 OF RESERVOIR INFLOWS AND OUTFLOWS'/// 1X,'TOWNS',10X,'SOURCES',8X
     2,'PUMP CAPACITY' / 35X,'(MGD)'  )
 2060 FORMAT (1H1)
 2070 FORMAT (1H+,46X,3A4,' DIVERTS AT ',3A4,' AT ',F5.1,' MGD AND FILLS
     1 ',3A4,' AT ',F5.1,' MGD ')
 2080 FORMAT (1H+,46X,3A4,' DIVERTS AT ',3A4,' AT ',F5.1,' MGD')
 2090 FORMAT (1H+,46X,3A4,' FILLS ',3A4,' AT ',F5.1,' MGD')
      END
```

……

```
      SUBROUTINE WANTX
C
C         SETS UP PARAMETERS FOR A SPECIAL PLOT TO BE CODED AND THEN CALLS
C            THE PLOT ROUTINE 'PLOTER'
C
C
      COMMON IITIME, ITIME, MAXCAP(60), NNODE, Q(60), STCAPY(60),
    1 TOWN(25), TYMFAC
      COMMON /M12/ DA(10), IMPMAX(12), IMPMIN(12), IMPNOD, IMPQ, IMPREC,
    1 IN, NRCRDS, NWELL, PERCNT(60,12), QQ(60), QSUBA(60), RECORD(60),
    2 RESDA(60), RESOOB(60), SUBADA(60), WELNOD(60), WELPCT(60)
      COMMON /M35/ DEFICT(25), DEMAND(25,12), GWMAX(25,12), IFLAG,
    1 IPRELM, IRTURN(25), MDCCAP(25), NTIME, NTOWN, PRIORY(25,16),
    2 RTURN(25,12), SWMAX(25,12), WELCAP(25,10,12)
      COMMON /M78/ CLASS(7), FREQ(10,8), MAXST(60), MINST(60), NOBS,
    1 OBS(10), OBSMAX(10), OBSMIN(10)
      COMMON /M568/ IDVRZN(60), IFILST(60), MAXMDC(25), NODNAM(63,3),
    1 OUT, SWSMAX(60,12), TTLDF(25), TTLDV(60), TTLMDC(25), IORDER(60)
      COMMON /M24/ EFF(60,12), UNIT(60,12), WELL(25,10)
      COMMON /S2356/ NPRINT, STMAX(60,12), SWMIN(60,12)
      COMMON /R2/ ITRZFL, ITRZST, QTRACE(120,9), FLTRAZ(120,9), IWANTX
      REAL IMPMAX, IMPMIN, IMPQ
      REAL MDCCAP
      REAL MAXST, MINST
```

```
      REAL MAXMOD
      REAL MAXCAP
      INTEGER RECORD, RESOOB, WELNOD
      INTEGER PRIORY
      INTEGER OBS
      INTEGER OUT
      INTEGER TOWN
      INTEGER WELL
      DIMENSION  A(120), B(120), C(120), D(120)
C
C
C          CALL PLOT ROUTINE 'PLOTER'
C
      WRITE (OUT,2000)
      CALL PLOTER (A,B,C,D)
      RETURN
      ENTRY WANTX1
      IF (IWANTX.EQ.98651) GO TO 10
      IWANTX = 98651
      DO 5 I = 1,120
      A(I) = 0.
      B(I) = 0.
      C(I) = 0.
    5 D(I) = 0.
C
C          USE THE FOUR TIME SERIES 'A','B','C', AND 'D' AND CODE ANY
C               VARIABLE DESIRED TO BE PLOTTED
C
   10 A(IITIME) = 0.
      C(IITIME) = 0.
      D(IITIME) = 0.
      B(IITIME) = 0.
      RETURN
C
C
 2000 FORMAT (1H1////5X,'AN EXTRA PLOT FOR THAT SOMETHING SPECIAL YOU WA
     1NTED' /////)
      END
------------------------------------------------------------------------------------
```

APPENDIX III

SAMPLE INPUT DECK

The following is a list of the data cards which causes the results of Appendix IV.

```
                                    COLUMN

         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890

56
EXAMPLE RUN FOR REPORT - ONE FEASIBLE ALTERNATIVE FOR 1995
            48117 20  9 38  3 24210  2  2  1
BURLINGTON
MAPLE MEADOW
WILMINGTON
READING WELL
READING
N READING
BEAR MEADOW
MARTIN BROOK
EISENHOUR PD
LYNNFIELD
LYNN
SAUGUS RIVER
HAWKES POND
WALDEN POND
BIRCH-BREEDS
PEABODY
SUNTAUG LAKE
SPRING LAKE
S MIDDLETON
PEABODY DIV
NORRIS BROOK
DANVERS-MIDD
DANVERS WELL
MIDDLETON PD
EMERSON POND
BOSTON BROOK
NICHOL BROOK
BOXFORD
SALEM-BEVRLY
WENHAM
HAMILTON
TOPSFIELD
GEORGETOWN
IPSWICH GAGE
IPSWICH WELL
ROWLEY
IPSWICH WELL
RES = 30-B
WENHAM LAKE
IPSWICH
ESSEX
GLOUCESTER
WALLACE-DIKE
BABSON-GOOSE
KLONDIKE
```

```
                                     COLUMN

         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890

MANCHESTER
ROCKPORT
IPSWICH DAM
IMPORT01  3  3
RECORD01  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  2  2  2  2  2
RECORD02  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2
WELNOD01  2  2  2  3  3  4  5  6  8  8  8  8  8 10 10 21 21 22 23 28 30 30 30 31
WELNOD02 32 33 33 35 36 37 38 38 39 39 41 41 46 47
TOWN  01  1  3  5  6 10 11 16 22 28 29 30 31 32 33 36 40 41 42 46 47
OBS   01  3  6 12 28 29 34 37 38 48
IRTURN01 48  3  5  6 10 48 16 22 48 48 30 31 32 48 48 40 48 48 48 48
PERCNT01 067 067 067 067 067 067 067 067 067 067 067 067
PERCNT02 132 132 132 132 132 132 132 132 132 132 132 132
PERCNT03 130 130 130 130 130 130 130 130 130 130 130 130
PERCNT04 012 012 012 012 012 012 012 012 012 012 012 012
PERCNT05 002 002 002 002 002 002 002 002 002 002 002 002
PERCNT06 023 023 023 023 023 023 023 023 023 023 023 023 023
PERCNT07 127 127 127 127 127 127 127 127 127 127 127 127
PERCNT08 337 337 337 337 337 337 337 337 337 337 337 337
PERCNT09 027 027 0270027 027 027 027 027 027 027 027 027
PERCNT10 062 062 062 062 062 062 062 062 062 062 062 062
PERCNT11
PERCNT12
PERCNT13
PERCNT14
PERCNT15
PERCNT16
PERCNT17
PERCNT18
PERCNT19 035 035 035 035 035 035 035 035 035 035 035 035
PERCNT20 001 001 001 001 001 001 001 001 001 001 001 001
PERCNT21 082 082 082 082 082 082 082 082 082 082 082 082
PERCNT22 005 005 005 005 005 005 005 005 005 005 005 005
PERCNT23 006 006 006 006 006 006 006 006 006 006 006 006
PERCNT24 021 021 021 021 021 021 021 021 021 021 021 021
PERCNT25 040 040 040 040 040 040 040 040 040 040 040 040
PERCNT26 219 219 219 219 219 219 219 219 219 219 219 219
PERCNT27 054 054 054 054 054 054 054 054 054 054 054 054
PERCNT28 233 233 233 233 233 233 233 233 233 233 233 233
PERCNT29 050005000500050005000500050005000500050005000500
PERCNT30 034 034 034 034 034 034 034 034 034 034 034 034
PERCNT31 046 046 046 046 046 046 046 046 046 046 046 046
PERCNT32 175 175 175 175 175 175 175 175 175 175 175 175
PERCNT33 023 023 023 023 023 023 023 023 023 023 023 023
PERCNT34 010001000100010001000100010001000100010001000100
PERCNT35 005 005 005 005 005 005 005 005 005 005 005 005
PERCNT36 030003000300030003000300030003000300030003000300
PERCNT37 005 005 005 005 005 005 005 005 005 005 005 005
```

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                                      COLUMN

         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890

PERCNT38 005 005 005 005 005 005 005 005 005 005 005 005
PERCNT39 225 225 225 225 225 225 225 225 225 225 225 225
PERCNT40 034 034 034 034 034 034 034 034 034 034 034 034
PERCNT41 004 004 004 004 004 004 004 004 004 004 004 004
PERCNT42
PERCNT43
PERCNT44
PERCNT45
PERCNT46
PERCNT47
PERCNT48
RESDA 01                                                                     104
RESDA 02    19    18    17           8     7                       5          16
RESDA 03    25                       9
RESDA 04          15    59     9           6    10    35     1     1     8
SURADA01    29    57    56     5     1    10    55   146    31    27
SURADA02                                        15     1    66     4     5    17
SURADA03    32   175    43   186    40    27    37   140    18     8     4    24
SURADA04     4     4   180    27     3
IFILST01                                  13 14 15       18             24
IFILST02 24          39
MAXCAP01                                                                    2000
MAXCAP02  2800 20000 19500        6000  5000                    1500        4000
MAXCAP03  3000                   17000
MAXCAP04      100000 12550   600        4000  3500  5000  1150  1360  1600
SWMINF0102
SWMAX 01
SWMAX 02
SWMAX 03
SWMAX 04
SWMAX 05
SWMAX 06
SWMAX 07
SWMAX 08
SWMAX 09
SWMAX 10
SWMAX 11
SWMAX 12
SWMAX 13
SWMAX 14
SWMAX 15
SWMAX 16
SWMAX 17
SWMAX 18
SWMAX 19
SWMAX 20
SWSMAX01
SWSMAX02
```

```
                                     COLUMN

         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890

SWSMAX03
SWSMAX04
SWSMAX05
SWSMAX06
SWSMAX07
SWSMAX08
SWSMAX09
SWSMAX10
SWSMAX11
SWSMAX12
SWSMAX13   100   100   100   100   100                                       100
SWSMAX14   100   100   100   100   100                                       100
SWSMAX15
SWSMAX16
SWSMAX17   200   200   200   200   200                                       200
SWSMAX18
SWSMAX19
SWSMAX20
SWSMAX21
SWSMAX22
SWSMAX23
SWSMAX24
SWSMAX25
SWSMAX26
SWSMAX27
SWSMAX28
SWSMAX29   250   250   250   250   250                                       250
SWSMAX30
SWSMAX31
SWSMAX32
SWSMAX33
SWSMAX34
SWSMAX35
SWSMAX36
SWSMAX37
SWSMAX38   400   400   400   400   400                                 400   400
SWSMAX39   250   250   250   250   250                                       250
SWSMAX40
SWSMAX41
SWSMAX42
SWSMAX43
SWSMAX44
SWSMAX45
SWSMAX46
SWSMAX47
SWSMAX48
STMAX 01
STMAX 02
```

```
                                        COLUMN

         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890

STMAX 03
STMAX 04
STMAX 05
STMAX 06
STMAX 07
STMAX 08
STMAX 09
STMAX 10
STMAX 11
STMAX 12    60    60    60    60    60    60    60    60    60    60    60    60
STMAX 13   200   200   200   200   200   200   200   200   200   200   200   200
STMAX 14   200   200   200   200   200   200   200   200   200   200   200   200
STMAX 15   240   240   240   240   240   240   240   240   240   24    240   240
STMAX 16
STMAX 17    56    56    56    56    56    56    56    56    56    56    56    56
STMAX 18   121   121   121   121   121   121   121   121   121   121   121   121
STMAX 19
STMAX 20
STMAX 21
STMAX 22     2     2     2     2     2     2     2     2     2     2     2     2
STMAX 23
STMAX 24    43    43    43    43    43    43    43    43    43    43    43    43
STMAX 25    10    10    10    10    10    10    10    10    10    10    10    10
STMAX 26
STMAX 27
STMAX 28
STMAX 29   250   250   250   250   250   250   250   250   250   250   250   250
STMAX 30
STMAX 31
STMAX 32
STMAX 33
STMAX 34
STMAX 35
STMAX 36
STMAX 37
STMAX 38   100   100   100   100   100   100   100   100   100   100   100   100
STMAX 39   240   240   240   240   240   240   240   240   240   240   240   240
STMAX 40     4     4     4     4     4     4     4     4     4     4     4     4
STMAX 41
STMAX 42    50    50    50    50    50    50    50    50    50    50    50    50
STMAX 43    45    45    45    45    45    45    45    45    45    45    45    45
STMAX 44    45    45    45    45    45    45    45    45    45    45    45    45
STMAX 45     8     8     8     8     8     8     8     8     8     8     8     8
STMAX 46    14    14    14    14    14    14    14    14    14    14    14    14
STMAX 47    10    10    10    10    10    10    10    10    10    10    10    10
STMAX 48
RES00B01                                   1  1  1  1     1  1           1
RES00B02                                         1     1     1  1  1  1  1  1
```

```
                                             COLUMN

         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890

DEMAND01
DEMAND02 771 672 753 788 892 937 944 993 882 847 762 759
DEMAND03 835 730 831 764 854 954 974 934 819 781 741 779
DEMAND04 780 683 920 769 826 9471098 1102 851 825 626 764
DEMAND05 745 635 721 746 94610121092 906 897 788 726 777
DEMAND06 799 727 807 802 843 890 945 965 862 837 735 778
DEMAND07 833 716 753 843 856 960 956 926 838 803 734 771
DEMAND08 769 748 836 767 845 912 942 977 840 834 752 779
DEMAND09 707 659 710 718 925 97711571086 881 736 724 712
DEMAND10 784 766 776 785 812 891 948 971 872 816 790 782
DEMAND11 679 623 693 755 871 808117312071049 618 659 660
DEMAND12 538 724 655 751 780 98812271149 874 782 761 760
DEMAND13 707 659 710 718 925 97711571086 881 736 724 712
DEMAND14 734 724 752 702 812 898 963 929 871 884 870 852
DEMAND15 777 729 823 872 817 982 958 959 804 713 796 764
DEMAND16 720 682 807 860 854100710351085 845 742 645 711
DEMAND17 539 464 502 690 798121014651207 1051 808 624 636
DEMAND18 779 692 721 764 808 917 9861037 895 828 773 791
DEMAND19 649 595 596 665 818100512771266 1004 776 666 669
DEMAND20 615 550 578 651 828118013381296 966 742 601 649
RTURN 01
RTURN 02 8   8   8   8   64  32  16  16  32  56  72  8
RTURN 03 2   2   2   2   16  08  04  04  08  14  18  2
RTURN 04
RTURN 05 2   2   2   2   16  08  04  04  08  14  18  2
RTURN 06
RTURN 07
RTURN 08 35  35  35  35  28  14  07  07  14  245 315 35
RTURN 09
RTURN 10
RTURN 111   1   1   1    8   4   2   2   4   7   9   1
RTURN 121   1   1   1    8   4   2   2   4   7   9   1
RTURN 131   1   1   1    8   4   2   2   4   7   9   1
RTURN 14
RTURN 15
RTURN 16 5   5   5   5   4   2   1   1   2   35  45  5
RTURN 17
RTURN 18
RTURN 19
RTURN 20
MDCCAP01                    40  40
MDCCAP02
PRIORY01
PRIORY02  1 48
PRIORY03  1 48
PRIORY04  1 48
PRIORY05  1 48
PRIORY06 25 48                    1
```

```
                                        COLUMN

         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890

PRIORY07                          1  2 28 48
PRIORY08  1 34 48
PRIORY09 48
PRIORY10 49 48
PRIORY11  1 48
PRIORY12  1 48
PRIORY13  1 48
PRIORY14  1 48
PRIORY15  1 48
PRIORY16  1 50 48
PRIORY17  1 48
PRIORY18 52 53 54 55 48
PRIORY19  1 56 48
PRIORY20  1 57 55 54 53 52 48
WELCAP01
WELCAP02144 144 144 144 144 144 144 144 144 144 144 144
WELCAP0313  13  13  13  13  13  13  13  13  13  13  13
WELCAP0405  05  05  05  05  05  05  05  05  05  05  05
WELCAP0505  05  05  05  05  05  05  05  05  05  05  05
WELCAP06072 0720072 072 072 072 072 072 072 072 072 072
WELCAP07144 144 144 144 144 144 144 144 144 144 144 144
WELCAP08086 086 086 086 086 086 086 086 086 086 086 086
WELCAP091   1   1   1   1   1   1   1   1   1   1   1
WELCAP10
WELCAP11144 1444144 144 144 144 144 144 144 144 144 144
WELCAP125   5   5   5   5   5   5   5   5   5   5   5
WELCAP13
WELCAP14065 065 065 065 065 065 065 065 065 065 065 065
WELCAP1504  04  04  04  04  04  04  04  04  04  04  04
WELCAP16072 072 072 072 072 072 072 072 072 072 072 072
WELCAP17
WELCAP18065 065 065 065 065 065 065 065 065 065 065 065
WELCAP1905  05  05  05  05  05  05  05  05  05  05  05  05
WELCAP20
WELCAP21
WELCAP22122 122 122 122 122 122 122 122 122 122 122 122
WELCAP23108 108 108 1081108 103 108 108 108 108 108 108
WELCAP24
WELCAP25144 144 144 144 144 144 144 144 144 144 144 144
WELCAP26094 094 094 094 094 094 094 094 094 094 094 094
WELCAP27
WELCAP28100
WELCAP29
WELCAP30
WELCAP31144 144 144 144 144 144 144 144 144 144 144 144
WELCAP32
WELCAP33108 108 108 108 108 108 108 108 108 108 108 108
WELCAP34043 043 043 043 043 043 043 043 043 043 043 043
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                                     COLUMN

         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890

WELCAP35036 036 036 036 036 036 036 036 036 036 036
WELCAP36032 032 032 032 032 032 032 032 032 032 032
WELCAP37
WELCAP3805  05  05  05  05  05  05  05  05  05  05
WELCAP39115 115 115 115 115 115 115 115 115 115 115 115 115
WELCAP40
WELCAP4104  04  04  04  04  04  04  04  04  04  04
WELCAP421   1   1   1   1   1   1   1   1   1   1
WELCAP43
WELCAP4405  05  05  05  05  05  05  05  05  05  05
WELCAP45
WELCAP46085 085 085 085 085 085 085 085 085 085 085
WELCAP47029 029 029 029 029 029 029 029 029 029 029
WELCAP48014 014 014 014 014 014 014 014 014 014 014 014
WELCAP4905  05  05  05  05  05  05  05  05  05  05
WELCAP50
WELCAP51064 064 064 064 064 064 064 064 06  064 064 064
WELCAP5205  05  05  05  05  05  05  05  05  05  05
WELCAP53
WELCAP54
WELCAP55086 086 086 086 086 086 086 086 086 086 086
WELCAP56
WELCAP57018 018 018 018 018 018 018 018 018 018 018 018 018
WELCAP58
WELPCT0105  06  07  02  05  11111111111103  03  03  03  06      02  05  03  1111
WELPCT021111    01  01  09  04  07          1111    1111        05  05
WELPCT03
WELL  01
WELL  02  1  2  3  4  5 11 12 13
WELL  03  6  7
WELL  04  8  9 10
WELL  05 14 15
WELL  06
WELL  07 16 17
WELL  08 18 19
WELL  09 20
WELL  10
WELL  11 21
WELL  12 22 23 33 34
WELL  13 24 25
WELL  14 26 27
WELL  15 29
WELL  16 28 30 31 32
WELL  17 35 36
WELL  18
WELL  19 37
WELL  20 38
IMPMAX01
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                                      COLUMN

         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890

IMPMIN01  9000  9000  9000  9000  9000  9000  9700  9700  9000  9000  9000  9000
CLASS 01    20    50   125   350   800  1400  3000
TYMFAC01 30.44
DA    01   434  1240 46350
CONSUP01    67  50  18  11  17.713.871  123 14.1079 18  22  06 057  27  08  62
CONSUP02157 192
UNIT  01.841  .054  .028  .018  .013  .010  .008  .007  .006  .005  .004  .004
UNIT  02.743  .095  .048  .030  .022  .017  .013  .011  .009  .008  .007  .006
UNIT  03.908  .031  .016  .011  .007  .006  .005  .004  .003  .003  .002  .002
UNIT  04.700  .097  .053  .035  .025  .019  .015  .013  .011  .009  .008  .007
UNIT  05.890  .037  .019  .012  .009  .007  .005  .004  .004  .003  .003  .003
UNIT  06.092  .144  .136  .116  .098  .084  .072  .062  .056  .050  .046  .042
UNIT  07.820  .058  .031  .020  .014  .009  .007  .006  .005  .004  .004  .003
UNIT  08.090  .145  .135  .115  .098  .085  .070  .061  .056  .050  .045  .040
UNIT  09.870  .044  .023  .015  .011  .008  .007  .006  .005  .004  .003  .003
UNIT  10.950  .017  .009  .006  .004  .003  .002  .002  .002  .001  .001  .001
UNIT  11.640  .116  .065  .043  .032  .025  .020  .017  .015  .013  .011  .009
UNIT  12.336  .176  .116  .083  .063  .050  .041  .035  .030  .026  .023  .020
UNIT  13.896  .036  .019  .012  .009  .007  .005  .004  .004  .003  .003  .002
UNIT  14
UNIT  15.782  .100  .049  .032  .023  .018  .014  .012  .010  .009  .007  .006
UNIT  16.950  .017  .009  .006  .004  .003  .002  .002  .001  .001  .001  .001
UNIT  17.918  .028  .015  .009  .007  .005  .004  .003  .003  .002  .002  .002
UNIT  18.762  .092  .050  .033  .024  .019  .016  .013  .011  .009  .007  .007
UNIT  19.938  .021  .011  .007  .005  .004  .003  .003  .002  .002  .002  .001
UNIT  20
UNIT  21.822  .027  .014  .009  .007  .004  .004  .003  .003  .002  .002  .002
UNIT  22.938  .021  .011  .007  .005  .004  .003  .003  .002  .002  .001  .001
UNIT  23.745  .085  .046  .030  .022  .017  .014  .012  .010  .008  .007  .006
UNIT  24.962  .013  .007  .005  .002  .002  .002  .001  .001  .001  .001  .001
UNIT  25.969  .010  .005  .003  .002  .002  .001  .001  .001  .001  .001  .001
UNIT  26
UNIT  27
UNIT  28.720  .093  .051  .033  .024  .019  .015  .012  .010  .009  .008  .007
UNIT  29
UNIT  30.793  .070  .037  .024  .018  .011  .009  .007  .006  .005  .005  .005
UNIT  31
UNIT  32
UNIT  33.164  .168  .133  .105  .085  .070  .060  .052  .044  .039  .035  .031
UNIT  34.588  .140  .080  .055  .040  .034  .026  .022  .018  .015  .013  .012
UNIT  35
UNIT  36
UNIT  37
UNIT  38
IDVRZN01                                    11 11       20
IDVRZN02             29                        38 29
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APPENDIX IV

SAMPLE OUTPUT

The following is part of the output of a run made with example data in the Ipswich River Basin.

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                       EXAMPLE RUN FOR REPCRT - CNE FEASIPLE ALTERNATIVE FCR 1995



   LIST OF TCWNS WATER RESCURCE SUPPLIFS              LIST OF RESERVOIR INFLOWS AND OUTFLOWS


TOWNS            SCURCES          PUMP CAPACITY
                                      (MGD)
BURLINGTON                                         SAUGUS RIVER FILLS HAWKES POND  AT    6.0 MGD
WILMINGTON                                         HAWKES POND  DIVERTS AT LYNN        AT  10.0 MGD AND FILLS WALDEN POND  AT  20.0 MGD
                 WELL NUMBER  1       1.44         WALDEN POND  DIVERTS AT LYNN        AT  10.0 MGD AND FILLS BIRCH-BREEDS AT  20.0 MGD
                 WELL NUMBER  2       1.30         SUNTAUG LAKE DIVERTS AT PEABODY DIV AT  20.0 MGD AND FILLS SPRING LAKE  AT   5.6 MGD
                 WELL NUMBER  3       0.50         CANVERS-MIDD FILLS MIDDLETCN PD AT  0.2 MGD
                 WELL NUMBER  4       0.50         EMERSCN PONC FILLS MIDDLETON PD AT  1.0 MGD
                 WELL NUMBER  5       0.72         SALEM-BEVRLY DIVERTS AT SALEM-BEVRLY AT  25.0 MGD AND FILLS WENHAM LAKE  AT  25.0 MGD
                 WELL NUMBER 11       1.44         RES # 30-B   DIVERTS AT RES # 30-B  AT  40.0 MGD
                 WELL NUMBER 12       0.86         WENHAM LAKE  DIVERTS AT SALEM-BEVRLY AT  25.0 MGD
                 WELL NUMBER 13       1.00
                 RES # 30-B          10.00
READING
                 WELL NUMBER  6       1.44
                 WELL NUMBER  7       5.00
                 RES # 30-B          10.00
N READING
                 WELL NUMBER  8       0.65
                 WELL NUMBER  9       0.40
                 WELL NUMBER 10       0.72
                 RES # 30-B          10.00
LYNNFIELD
                 WELL NUMBER 14       0.65
                 WELL NUMBER 15       0.50
                 RES # 30-B          10.00
LYNN
                 BIRCH-BREECS        24.00
                 RES # 30-B          10.00
                 TREATED IMPCRT       4.00
PEABODY
                 TREATEC IMPCRT       4.00
                 WELL NUMBER 16       1.22
                 WELL NUMBER 17       1.08
                 SPRING LAKF         12.10
                 RES # 30-B          10.00
DANVERS-MICD
                 WELL NUMBER 18       1.44
                 WELL NUMBER 19       0.94
                 MIDDLETCN PD         4.30
                 RES # 30-B          10.00
BCXFCRD
                 RES # 30-B          10.00
SALEM-BEVRLY
                 WENHAM LAKE         24.00
                 RES # 30-B          10.00
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                                               26.0 MG WAS DIVERTED FROM SAUGUS RIVER TO HAWKES POND  IN MONTH NUMBER  68
                                               30.7 MG WAS DIVERTED FROM HAWKES POND  TO WALDEN POND  IN MONTH NUMBER  68
                                               35.2 MG WAS DIVERTED FROM WALDEN POND  TO BIRCH-BREEDS IN MONTH NUMBER  68
                                                2.0 MG WAS DIVERTED FROM SUNTAUG LAKE TO SPRING LAKE  IN MONTH NUMBER  68
                                                6.1 MG WAS DIVERTED FROM DANVERS-MIDD TO MIDDLETON PD IN MONTH NUMBER  68
                                               30.4 MG WAS DIVERTED FROM EMERSON POND TO MIDDLETON PD IN MONTH NUMBER  68
                                              500.1 MG WAS DIVERTED FROM SALEM-BEVRLY TO WENHAM LAKE  IN MONTH NUMBER  68
LYNN         HAD A DEFICIT OF   2.9852 MGD IN MONTH NUMBER  69
                                               31.0 MG WAS DIVERTED FROM SAUGUS RIVER TO HAWKES POND  IN MONTH NUMBER  69
                                               36.7 MG WAS DIVERTED FROM HAWKES POND  TO WALDEN POND  IN MONTH NUMBER  69
                                               42.1 MG WAS DIVERTED FROM WALDEN POND  TO BIRCH-BREEDS IN MONTH NUMBER  69
                                                2.4 MG WAS DIVERTED FROM SUNTAUG LAKE TO SPRING LAKE  IN MONTH NUMBER  69
                                                6.1 MG WAS DIVERTED FROM DANVERS-MIDD TO MIDDLETON PD IN MONTH NUMBER  69
                                               30.4 MG WAS DIVERTED FROM EMERSON POND TO MIDDLETON PD IN MONTH NUMBER  69
                                              259.1 MG WAS DIVERTED FROM SALEM-BEVRLY TO WENHAM LAKE  IN MONTH NUMBER  69
LYNN         HAD A DEFICIT OF   2.1525 MGD IN MONTH NUMBER  70
                                               45.2 MG WAS DIVERTED FROM SAUGUS RIVER TO HAWKES POND  IN MONTH NUMBER  70
                                               53.5 MG WAS DIVERTED FROM HAWKES POND  TO WALDEN POND  IN MONTH NUMBER  70
                                               61.3 MG WAS DIVERTED FROM WALDEN POND  TO BIRCH-BREEDS IN MONTH NUMBER  70
                                                3.5 MG WAS DIVERTED FROM SUNTAUG LAKE TO SPRING LAKE  IN MONTH NUMBER  70
                                                6.1 MG WAS DIVERTED FROM DANVERS-MIDD TO MIDDLETON PD IN MONTH NUMBER  70
                                               30.4 MG WAS DIVERTED FROM EMERSON POND TO MIDDLETON PD IN MONTH NUMBER  70
                                                1.8 MG WAS DIVERTED FROM SALEM-BEVRLY TO WENHAM LAKE  IN MONTH NUMBER  70
                                               57.6 MG WAS DIVERTED FROM SAUGUS RIVER TO HAWKES POND  IN MONTH NUMBER  71
                                               68.1 MG WAS DIVERTED FROM HAWKES POND  TO WALDEN POND  IN MONTH NUMBER  71
                                               78.1 MG WAS DIVERTED FROM WALDEN POND  TO BIRCH-BREEDS IN MONTH NUMBER  71
                                                4.4 MG WAS DIVERTED FROM SUNTAUG LAKE TO SPRING LAKE  IN MONTH NUMBER  71
                                                6.1 MG WAS DIVERTED FROM DANVERS-MIDD TO MIDDLETON PD IN MONTH NUMBER  71
                                               30.4 MG WAS DIVERTED FROM EMERSON POND TO MIDDLETON PD IN MONTH NUMBER  71
                                                2.3 MG WAS DIVERTED FROM SALEM-BEVRLY TO WENHAM LAKE  IN MONTH NUMBER  71
                                                                       WALDEN POND  DIVERTED    6.5 MG IN MONTH NUMBER   72
                                               69.6 MG WAS DIVERTED FROM SAUGUS RIVER TO HAWKES POND  IN MONTH NUMBER  72
                                               82.3 MG WAS DIVERTED FROM HAWKES POND  TO WALDEN POND  IN MONTH NUMBER  72
                                              100.9 MG WAS DIVERTED FROM WALDEN POND  TO BIRCH-BREEDS IN MONTH NUMBER  72
                                                5.4 MG WAS DIVERTED FROM SUNTAUG LAKE TO SPRING LAKE  IN MONTH NUMBER  72
                                                6.1 MG WAS DIVERTED FROM DANVERS-MIDD TO MIDDLETON PD IN MONTH NUMBER  72
                                               30.4 MG WAS DIVERTED FROM EMERSON POND TO MIDDLETON PD IN MONTH NUMBER  72
                                                3.3 MG WAS DIVERTED FROM SALEM-BEVRLY TO WENHAM LAKE  IN MONTH NUMBER  72
SALEM-BEVRLY HAD A DEFICIT OF   2.2785 MGD IN MONTH NUMBER  73
                                                                       WALDEN POND  DIVERTED   33.9 MG IN MONTH NUMBER   73
                                               75.5 MG WAS DIVERTED FROM SAUGUS RIVER TO HAWKES POND  IN MONTH NUMBER  73
                                               89.3 MG WAS DIVERTED FROM HAWKES POND  TO WALDEN POND  IN MONTH NUMBER  73
                                              136.3 MG WAS DIVERTED FROM WALDEN POND  TO BIRCH-BREEDS IN MONTH NUMBER  73
                                                5.8 MG WAS DIVERTED FROM SUNTAUG LAKE TO SPRING LAKE  IN MONTH NUMBER  73
                                                6.1 MG WAS DIVERTED FROM DANVERS-MIDD TO MIDDLETON PD IN MONTH NUMBER  73
                                               30.4 MG WAS DIVERTED FROM EMERSON POND TO MIDDLETON PD IN MONTH NUMBER  73
                                                4.1 MG WAS DIVERTED FROM SALEM-BEVRLY TO WENHAM LAKE  IN MONTH NUMBER  73
PEABODY      HAD A DEFICIT OF   4.8710 MGD IN MONTH NUMBER  74
SALEM-BEVRLY HAD A DEFICIT OF   8.1588 MGD IN MONTH NUMBER  74
TOPSFIELD    HAD A DEFICIT OF   0.0898 MGD IN MONTH NUMBER  74
IPSWICH      HAD A DEFICIT OF   0.0297 MGD IN MONTH NUMBER  74
GLOUCESTER   HAD A DEFICIT OF   1.4696 MGD IN MONTH NUMBER  74
MANCHESTER   HAD A DEFICIT OF   0.1902 MGD IN MONTH NUMBER  74
ROCKPORT     HAD A DEFICIT OF   0.5212 MGD IN MONTH NUMBER  74
                                                                       WALDEN POND  DIVERTED  283.3 MG IN MONTH NUMBER   74
                                                                       SUNTAUG LAKE DIVERTED   28.5 MG IN MONTH NUMBER   74
                                                                       SALEM-BEVRLY DIVERTED  648.9 MG IN MONTH NUMBER   74
                                                                       RES # 30-B   DIVERTED  311.6 MG IN MONTH NUMBER   74
                                              182.6 MG WAS DIVERTED FROM SAUGUS RIVER TO HAWKES POND  IN MONTH NUMBER  74
                                              223.6 MG WAS DIVERTED FROM HAWKES POND  TO WALDEN POND  IN MONTH NUMBER  74
                                              545.6 MG WAS DIVERTED FROM WALDEN POND  TO BIRCH-BREEDS IN MONTH NUMBER  74
                                               45.8 MG WAS DIVERTED FROM SUNTAUG LAKE TO SPRING LAKE  IN MONTH NUMBER  74
                                                6.1 MG WAS DIVERTED FROM DANVERS-MIDD TO MIDDLETON PD IN MONTH NUMBER  74
                                               30.4 MG WAS DIVERTED FROM EMERSON POND TO MIDDLETON PD IN MONTH NUMBER  74
                                              669.0 MG WAS DIVERTED FROM SALEM-BEVRLY TO WENHAM LAKE  IN MONTH NUMBER  74
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OBSERVATION NODE   MAX MONTHLY FLOW   MIN MONTHLY FLOW                        FREQUENCY TABLE  (MGD)
                         (MGD)              (MGD)       0. <Q<    2. <Q<    5. <Q<  13. <Q<  35. <Q<  80. <Q< 140. <Q< 300. <Q
  WILMINGTON              52.               1.71          0.034     0.239     0.282     0.342     0.103     0.0       0.0       0.0
  N READING               48.               0.90          0.179     0.239     0.265     0.274     0.043     0.0       0.0       0.0
  S MIDDLETON            133.               2.48          0.0       0.162     0.299     0.308     0.145     0.085     0.0       0.0
  BOXFORD                334.               4.88          0.0       0.009     0.222     0.179     0.325     0.111     0.120     0.034
  SALEM-BEVRLY           337.               5.09          0.0       0.0       0.222     0.359     0.179     0.094     0.120     0.026
  IPSWICH GAGE           432.               7.01          0.0       0.0       0.137     0.248     0.291     0.128     0.162     0.034
  IPSWICH WELL           443.               6.19          0.0       0.0       0.154     0.222     0.299     0.128     0.154     0.043
  RES # 30-B             430.               6.21          0.0       0.0       0.154     0.402     0.179     0.068     0.162     0.034
  IPSWICH DAM            518.               7.78          0.0       0.0       0.077     0.316     0.265     0.137     0.094     0.111
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RIVER POINT    STORAGE CAPACITY  MAX STORAGE  MIN STORAGE  FLOW DIVERTED  WATER PURCHASED  MAX MONTHLY PURCHASE  TOTAL DEFICIT
                     (MG)           (MG)         (MG)          (MG)            (MG)                (MG)               (MG)
BURLINGTON             0.             0.           0.            0.             0.0                 0.0                0.
MAPLE MEADOW           0.             0.           0.            0.
WILMINGTON             0.             0.           0.            0.             0.0                 0.0                0.
READING WELL           0.             0.           0.            0.
READING                0.             0.           0.            0.             0.0                 0.0                0.
N READING              0.             0.           0.            0.             0.0                 0.0                0.
BEAR MEADOW            0.             0.           0.            0.
MARTIN BROOK           0.             0.           0.            0.
EISENHOUR PD           0.             0.           0.            0.
LYNNFIELD              0.             0.           0.            0.             0.0                 0.0                0.
LYNN                   0.             0.           0.            0.          1541.1               121.8             1190.
SAUGUS RIVER         200.           200.           0.            0.
HAWKES POND          280.             0.           0.         8844.
WALDEN POND         2000.           451.           0.        17110.
BIRCH-BREEDS        1950.          1647.          35.            0.
PEABODY                0.             0.           0.            0.         14245.7               121.8             1217.
SUNTAUG LAKE         600.           430.           0.         9896.
SPRING LAKE          500.           489.           2.            0.
S MIDDLETON            0.             0.           0.            0.
PEABODY DIV            0.             0.           0.            0.
NORRIS BROOK           0.             0.           0.            0.
DANVERS-MIDD         150.           144.         118.            0.             0.0                 0.0              264.
DANVERS WELL           0.             0.           0.            0.
MIDDLETON PD         400.           192.          37.            0.
EMERSON POND         300.           270.         103.            0.
BOSTON BROOK           0.             0.           0.            0.
NICHOL BROOK           0.             0.           0.            0.
BOXFORD                0.             0.           0.            0.             0.0                 0.0              105.
SALEM-BEVRLY        1700.          1700.           0.        21519.             0.0                 0.0              415.
WENHAM                 0.             0.           0.            0.             0.0                 0.0                0.
HAMILTON               0.             0.           0.            0.             0.0                 0.0                0.
TOPSFIELD              0.             0.           0.            0.             0.0                 0.0               47.
GEORGETOWN             0.             0.           0.            0.             0.0                 0.0                0.
IPSWICH GAGE           0.             0.           0.            0.
IPSWICH WELL           0.             0.           0.            0.
ROWLEY                 0.             0.           0.            0.             0.0                 0.0                4.
IPSWICH WELL           0.             0.           0.            0.
RES # 30-B         10000.         10000.           0.        39599.
WENHAM LAKE         1255.          1255.           3.        20747.
IPSWICH               60.            51.           0.            0.             0.0                 0.0               29.
ESSEX                  0.             0.           0.            0.             0.0                 0.0                0.
GLOUCESTER           400.             0.           0.            0.             0.0                 0.0              610.
WALLACE-DIKE         350.            28.           0.            0.
BABSON-GOOSE         500.           500.           0.            0.
KLONDIKE             115.             6.           0.            0.
MANCHESTER           136.             2.           0.            0.             0.0                 0.0              120.
ROCKPORT             160.           102.           0.            0.             0.0                 0.0              243.
IPSWICH DAM            0.             0.           0.            0.
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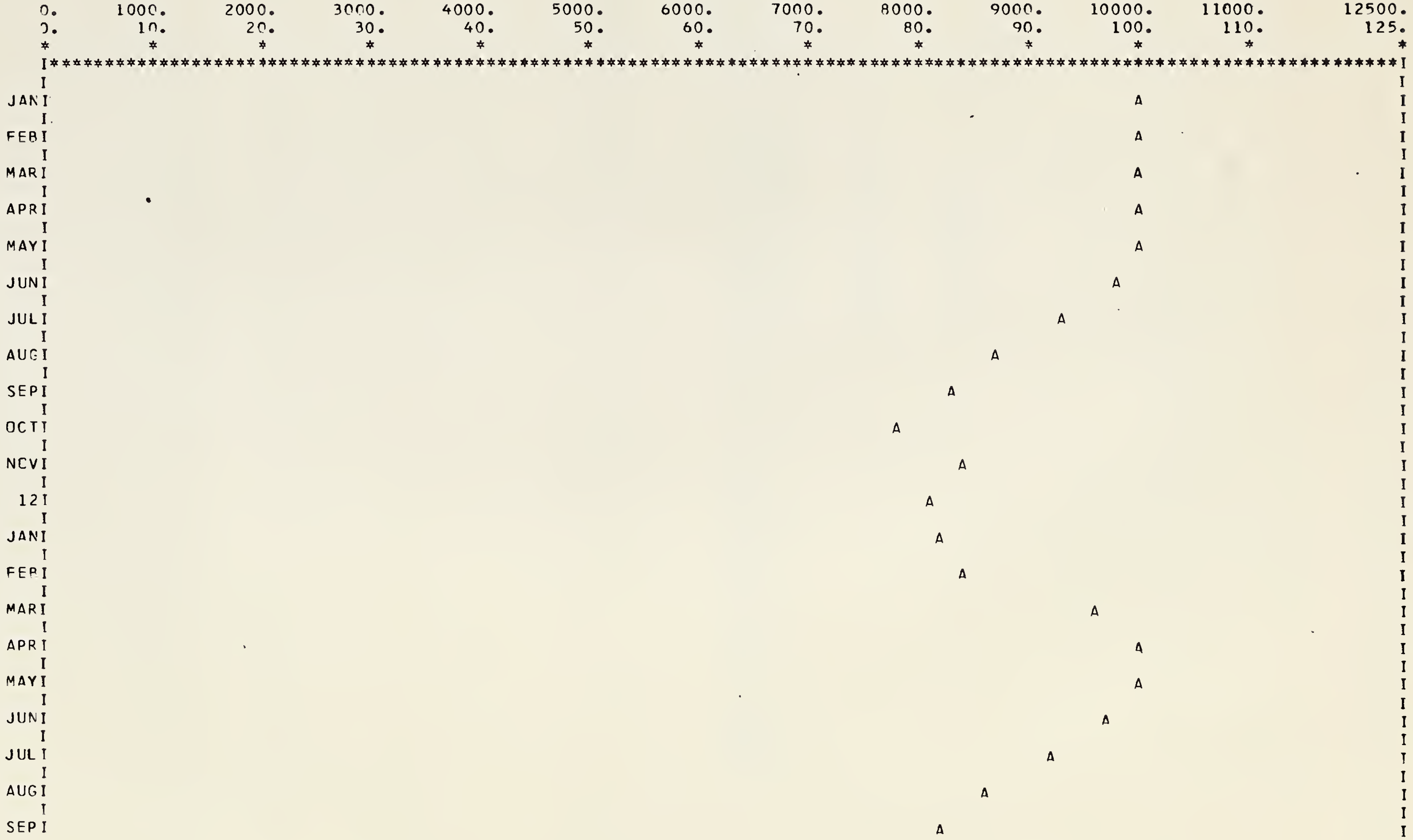
                                  FLOW TRACE AT INDICATED POINT   (MGD)
MONTH   WILMINGTON  N READING   S MIDDLETON  BOXFORD     SALEM-BEVRLY IPSWICH GAGE IPSWICH WELL RES # 30-B   IPSWICH DAM
  1        16.67        9.51       17.80       71.48       36.53       62.55       64.86       36.29       59.67
  2        30.93       23.06       67.75      190.57      161.39      221.33      227.22      227.13      278.15
  3        24.38       15.82       41.77      115.38      108.97      147.18      150.08      148.21      183.53
  4        36.28       31.09       82.36      217.47      215.56      280.73      287.71      286.78      347.20
  5        17.81       17.38       28.23       76.15       66.66       93.00       95.56       92.00      115.44
  6        10.27        8.11       26.04       57.55       60.26       75.98       77.20       77.47       92.28
  7         2.51        1.45        4.72       12.04       12.63       16.58       16.20       16.28       20.50
  8         2.36        1.50        4.16        8.59        8.99       11.65       11.03       11.09       14.00
  9         5.76        2.66       12.67       21.88       22.58       27.82       27.48       27.57       32.63
 10         7.24        4.47       14.82       26.60       27.42       34.63       34.40       34.51       39.11
 11        10.99        5.53       25.09       47.96       49.50       62.37       62.87       25.34       33.55
 12        11.30        6.01        9.39       30.39       20.02       32.63       33.02       25.34       33.29
 13        14.88        9.09       13.16       41.26       20.02       37.30       38.43       25.34       36.84
 14        15.01        9.23       15.87       35.29       20.02       34.97       34.47       25.34       35.33
 15        41.38       33.84       96.55      232.15      203.66      274.39      281.87      243.12      300.93
 16        47.71       43.85      115.55      309.78      284.29      374.86      385.41      377.94      461.82
 17        23.65       23.90       46.18      120.56      113.12      151.12      155.32      151.99      186.20
 18         9.23        6.94       22.90       54.95       57.70       73.66       74.92       75.19       90.22
 19         3.10        1.49        6.58       15.90       16.63       21.49       21.25       21.34       26.46
 20         2.36        1.50        4.16        9.12        9.56       12.43       11.85       11.91       15.06
 21         9.57        2.98       22.07       44.03       45.57       56.63       57.17       57.37       68.15
 22        15.15        8.65       34.41       88.07       91.59      118.37      120.94      121.39      140.24
 23        17.79       15.62       44.33       87.53       90.33      112.70      114.51       74.87       89.25
 24        16.39       14.18       21.66       65.04       20.02       48.40       50.98       25.34       43.65
 25        25.19       23.85       47.89      116.76       83.43      121.37      125.35       92.82      127.21
 26        11.75        6.07        9.56       45.18       29.24       47.79       47.87       44.29       57.06
 27        41.33       32.57       92.54      225.60      223.94      289.18      295.99      294.58      354.88
 28        34.65       29.25       76.39      221.06      219.77      288.44      295.91      294.99      358.64
 29        18.53       18.18       30.22       86.12       77.26      107.18      110.25      106.74      133.49
```

```
                         RESERVOIR STORAGE TRACE AT INDICATED POINT   (MG)
MONTH    WILMINGTON   N READING   S MIDDLETON  BOXFORD     SALEM-BEVRLY IPSWICH GAGE IPSWICH WELL RES # 30-B   IPSWICH DAM
  1         0.0          0.0          0.0         0.0        885.62        0.0          0.0      10000.00        0.0
  2         0.0          0.0          0.0         0.0       1700.00        0.0          0.0      10000.00        0.0
  3         0.0          0.0          0.0         0.0       1700.00        0.0          0.0      10000.00        0.0
  4         0.0          0.0          0.0         0.0       1700.00        0.0          0.0      10000.00        0.0
  5         0.0          0.0          0.0         0.0       1700.00        0.0          0.0      10000.00        0.0
  6         0.0          0.0          0.0         0.0       1241.09        0.0          0.0       9753.85        0.0
  7         0.0          0.0          0.0         0.0        758.07        0.0          0.0       9333.53        0.0
  8         0.0          0.0          0.0         0.0        261.54        0.0          0.0       8745.62        0.0
  9         0.0          0.0          0.0         0.0          0.0         0.0          0.0       8309.45        0.0
 10         0.0          0.0          0.0         0.0          0.0         0.0          0.0       7759.20        0.0
 11         0.0          0.0          0.0         0.0          0.0         0.0          0.0       8406.64        0.0
 12         0.0          0.0          0.0         0.0          0.0         0.0          0.0       8095.92        0.0
 13         0.0          0.0          0.0         0.0          0.0         0.0          0.0       8172.90        0.0
 14         0.0          0.0          0.0         0.0          0.0         0.0          0.0       8367.04        0.0
 15         0.0          0.0          0.0         0.0        846.21        0.0          0.0       9631.51        0.0
 16         0.0          0.0          0.0         0.0       1700.00        0.0          0.0      10000.00        0.0
 17         0.0          0.0          0.0         0.0       1700.00        0.0          0.0      10000.00        0.0
 18         0.0          0.0          0.0         0.0       1241.09        0.0          0.0       9690.76        0.0
 19         0.0          0.0          0.0         0.0        759.25        0.0          0.0       9241.08        0.0
 20         0.0          0.0          0.0         0.0        263.02        0.0          0.0       8647.10        0.0
 21         0.0          0.0          0.0         0.0          0.0         0.0          0.0       8238.22        0.0
 22         0.0          0.0          0.0         0.0          0.0         0.0          0.0       7824.88        0.0
 23         0.0          0.0          0.0         0.0          0.0         0.0          0.0       8666.53        0.0
 24         0.0          0.0          0.0         0.0        705.35        0.0          0.0       9023.95        0.0
 25         0.0          0.0          0.0         0.0       1509.96        0.0          0.0      10000.00        0.0
 26         0.0          0.0          0.0         0.0       1700.00        0.0          0.0      10000.00        0.0
 27         0.0          0.0          0.0         0.0       1700.00        0.0          0.0      10000.00        0.0
 28         0.0          0.0          0.0         0.0       1700.00        0.0          0.0      10000.00        0.0
 29         0.0          0.0          0.0         0.0       1700.00        0.0          0.0      10000.00        0.0
```

```
A PLOT FOR THE PERIOD OF RECORD

          IF MORE THAN ONE SCALE APPEARS, THE FIRST IS FOR SYMBOLS A AND C
          AND THE INNER IS FOR SYMBOLS B AND D.

                    X REPRESENTS MORE THAN ONE VARIABLE AT A POINT
                    A REPRESENTS STOR FOR RES # 30-B
```



APPENDIX V

WELL EFFECTS

The following is a listing of the Fortran IV source deck of the program used to compute the effects of well pumpages on the river; a list of the data cards used; and part of the output from the program.

```
C
C             PROGRAM FOR COMPUTING WELL EFFECT ON STREAMS
C
C
C             SEE U.S. GEOLOGICAL SURVEY WATER RESOURCE INVESTIGATION
C                  SERIES - BOOK 4 CHAPTER D1 BY C.T. JENKINS FOR
C                  PHILOSOPHY .
C
C             THIS PROGRAM WAS CODED BY I.C. JAMES,II, U.S.GEOLOGICAL
C                  SURVEY, WATER RESOURCES DIVISION, BOSTON MASSACHUSETTS.
C
C
      DIMENSION Q(12), QQ(12)
C
      WRITE(6,167)
C
C     TRANS = TRANSMISSIVITY
C     S = STORAGE COEFFICIENT
C     A = DISTANCE FROM STREAM TO WELL
C
    5 READ (5,1,END=200) A,TRANS,S,NOWELL
      TRANS = TRANS/7.5
      WRITE (6,2) NOWELL
C
      CUM=0.0
      SM=0.0
      DO 10 I=1,9
      T = 3.04*FLOAT(I)
      F = 1.-ERF (A/SQRT(4.*T*TRANS/S))
      SM = SM + F
   10 CONTINUE
      T=30.4
      F = 1.-ERF (A/SQRT(4.*T*TRANS/S))
      SM = SM + F/2.
      Q(1) = SM/10.
      CUM = CUM + Q(1)
      DO 20 J=2,12
      SM=0.0
      TL = 30.4*FLOAT(J-1)
      SM = SM + F/2.
      DO 15 I=1,9
      T = 3.04*FLOAT(I) + TL
      F=ERF(A/SQRT(4.*(T-30.4)*TRANS/S))-ERF(A/SQRT(4.*T*TRANS/S))
      SM = SM + F
   15 CONTINUE
      T = 30.4*TL
      F=ERF(A/SQRT(4.*(T-30.4)*TRANS/S))-ERF(A/SQRT(4.*T*TRANS/S))
      SM = SM + F/2.
      Q(J) = SM/10.
      CUM = CUM + Q(J)
   20 CONTINUE
      DO 21 J = 1,12
```

```
   21 QQ(J) = Q(J)/CUM
      DO 25 J=13,120
      T   = 30.4*FLOAT(J-1) + 15.2
      F=ERF(A/SQRT(4.*(T-30.4)*TRANS/S))-ERF(A/SQRT(4.*T*TRANS/S))
      CUM = CUM + F
   25 CONTINUE
      WRITE(6,101) A,S,TRANS
      QSUM = 0.
      DO 30 I=1,12
      Q(I) = Q(I)/CUM
   30 QSUM = QSUM + Q(I)
      WRITE(6,102) Q
      WRITE(6,103) QSUM
      WRITE(6,104) QQ
      GO TO 5
  200 STOP
C
C
  167 FORMAT(1H1)
    1 FORMAT (3F10.0,I5)
    2 FORMAT (//////////1X,'WELL NUMBER',I5)
  101 FORMAT (1X,'DISTANCE A=',F5.0,' FT,    STORAGE COEF=',F5.3,    '
     $TRANSMISSIVITY=',F8.0,//)
  102 FORMAT(1X,'MONTHLY RESPONSE',12F9.5)
  103 FORMAT(1X,'12 MONTH CUMULATIVE RESPONSE=',F9.5)
  104 FORMAT(1X,'RESCALED RESPONSE',12F9.5,////)
      END
```

```
                       LISTING OF THE DATA CARDS

                                COLUMN

         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890

       500     58000     .25      1
      1000     94000     .25      2
       250     42000     .25      3
       750     40000     .25      4
       400     76000     .25      5
      4000     56000     .25      6
       400     33000     .25      7
      3000     45000     .25      8
       300     31000     .25      9
       150     48000     .25     10
      1000     50000     .25     11
      1800     45000     .25     12
       250     32000     .25     13
       750     48000     .25     15
       200     88000     .25     16
       300     74000     .25     17
       600     30000     .25     18
       220     68000     .25     19
       300     80000     .25     20
       250     87000     .25     21
       600     34000     .25     22
       100     35000     .25     23
       100     55000     .25     24
       500     20000     .25     28
       500     35000     .25     29
      2100     32000     .25     32
       750     21000     .25     33
```

```
WELL NUMBER     7
DISTANCE A= 400. FT,   STORAGE COEF=0.250    TRANSMISSIVITY=   4400.

MONTHLY RESPONSE  0.57708  0.25326  0.05679  0.03002  0.01935  0.01381  0.01049  0.00833  0.00681  0.00571  0.00488  0.00423
12 MONTH CUMULATIVE RESPONSE=  0.99075
RESCALED RESPONSE  0.58247  0.25563  0.05732  0.03030  0.01953  0.01394  0.01059  0.00840  0.00688  0.00576  0.00492  0.00427
```

```
WELL NUMBER     8
DISTANCE A=3000. FT,   STORAGE COEF=0.250    TRANSMISSIVITY=   6000.

MONTHLY RESPONSE  0.00544  0.08065  0.13887  0.12975  0.10949  0.09146  0.07709  0.06581  0.05689  0.04974  0.04394  0.03916
12 MONTH CUMULATIVE RESPONSE=  0.88828
RESCALED RESPONSE  0.00613  0.09079  0.15634  0.14607  0.12326  0.10297  0.08679  0.07408  0.06404  0.05600  0.04946  0.04408
```

```
WELL NUMBER     9
DISTANCE A= 300. FT,   STORAGE COEF=0.250    TRANSMISSIVITY=   4133.

MONTHLY RESPONSE  0.65598  0.21478` 0.04356  0.02288  0.01471  0.01048  0.00796  0.00631  0.00516  0.00432  0.00369  0.00320
12 MONTH CUMULATIVE RESPONSE=  0.99302
RESCALED RESPONSE  0.66059  0.21629  0.04386  0.02304  0.01481  0.01055  0.00801  0.00635  0.00520  0.00435  0.00372  0.00322
```

REFERENCES CITED

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